Multilateral Bargaining and Strategic Investments in the Eurasian Gas Supply Network

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Abstract

This thesis consists of three related essays, which develop the framework to study multilateral bargaining and strategic investments under three different environments. The introduced novel methodologies are applied to analyze developments in the Eurasian gas supply chain.

The first analytical part of the thesis concerns multilateral bargaining Russia and transiters for its gas, Ukraine, Belarus, and Poland. The players are assumed to be heterogeneous, some lacking the ability to make long-term commitments. We apply a two stage game to analyze distortions of investments into the pipeline system supplying Russian gas to Western Europe. Our qualitative and quantitative analysis provides a strategic rational behind excess capacities, which were built, and explains over/underinvestment as an attempt to create countervailing power.

The second part of the thesis deals with multilateral bargaining and coalition formation issues in the presence of externalities. We study whether two competing supply chains, Russian vs. Caspian, are likely to be formed or monopoly supply will be organized. We quantify the strategic value of different investment options. We examine how the bargaining power of the network players depends on the architecture of the existing network and its possible extensions. We show why the players form a grand coalition in equilibrium.

The third study focuses on coalition formation and bargaining in the environment with externalities under the hold-up. Using a two stage game we study how the inability of players to commit to long-term profit sharing may lead to strategic distortions in investments. We find that under/overinvestment

are likely to happen in the future, if the players will not be able to build stable long-term relation.

Keywords:
strategic investments, bargaining, hold-up, gas supply

Zusammenfassung

Diese Arbeit besteht aus drei zusammengehoerigen Essays, die eine theoretische Grundlage füer Untersuchungen multilateraler Verhandlungen und strategischer Investitionen liefert. Die vorgestellten Methoden werden angewandt um Entwicklungen in der eurasischen Gasversorgung zu analysieren.

Der erste analytische Teil befasst sich mit multilateralen Verhandlungen zwischen Russland und den Transitstaaten fuer sein Gas. Es wird angenommen dass die beteiligten Laender heterogen: einige von ihnen nicht die Faehigkeit besitzen langfristige Zusagen zu machen. Wir wenden ein zweistufiges spieltheoretisches Konzept an um Verzerrungen in Investitionen in das Pipeline System zu analysieren. Unsere Analyse liefert eine strategische Begruendung fuer den Ueberschuss an gebauten Kapazitaeten und erklaert Ueber/Unterinvestitionen als ein Versuch ein Kraeftegleichgewicht zu erzeugen.

Der zweite Teil beschaeftigt sich mit multilateralen Verhandlungen und der Etablierung von Buendnissen in der Gegenwart von externen Effekten. Wir untersuchen ob zwei konkurrierender Versorgungsketten, der russischen und der kaspischen, wahrscheinlich sind oder ob sich eher ein Monopol in der Versorgung herausbildet. Wir gehen auf die Fragestellung ein, wie die Verhandlungsmacht der Beteiligten in diesem Netzwerk von der Struktur des bestehenden Netzwerks und seiner moeglichen Aenderungen abhaengt.

Die dritte Studie richtet sich auf die Formation von Koalitionen in einem Umfeld mit verzoegerten externen Effekten. Indem wir ein zweistufiges Spiel benutzen, untersuchen wir, wie die Unfaehigkeit der Spieler zu einem langfristigen geteilten Gewinn beizutragen zu strategischen Verzerrungen in Investitionen fuehren kann. Wir finden heraus, dass Unter/Ueberinvestitionen in der Zukunft wahrscheinlich sind, wenn die Spieler nicht in der Lage sein werden langfristige Beziehungen miteinander einzugehen.

Schlagwörter:
Investitionen, Verhandlungen, Verzögerungen, Gasversorgung

Contents

Introduction

Natural gas is an environment-friendly source of energy. Its share in the EU primary energy consumption is over 20% at present and it is likely to increase in the future. While the consumption of gas in Europe is growing, its domestic production is declining, so a substantial part of gas is imported. Over a quarter of the total consumption is satisfied with gas from the Former Soviet Union (FSU). Since alternative producers, like Algeria, Norway, and exporters of liquified natural gas, are not able to increase their supplies considerably, the dependency on FSU gas will grow. This fact raises concerns on reliability and security of supplies from FSU.

In the past, a network of pipelines was built to deliver gas from the Soviet Union, namely from Russia and Caspian Republics, including Turkmenistan, Kazakhstan, Azerbaijan, and Uzbekistan, to the European market. The pipelines of the Eurasian gas network pass across Russia, Ukraine, and Eastern European countries connecting fields with the Western European transport system. All issues related to the production and transportation of gas, were resolved centrally. After the collapse of the Soviet Union, most of the Republics became independent countries, each pursuing its own interests. Russia inherited the majority of gas fields and all export routes linking Caspian producers with the European market. To insure its revenues, Russia blocked the access to its export pipeline system and squeezed out potential competitors, establishing itself as the only gas exporter in the region.

For the delivery of its gas to the markets in Western Europe Russia depended on newly independent Ukraine through which all export routes went. Ukraine exploited its control over the essential transport capacities as a bargaining chip in negotiations with Russia. To gain leverage over the transiter and strengthen its bargaining position, Russia decided to diversify its export routes and establish a new path to Europe. Although it would have been enough to upgrade and renovate the Ukrainian transport system to satisfy the sluggish demand, a pipeline through Belarus and Poland was built in the late 90ies. The new pipeline, commonly referred to as Yamal, was twice as expensive as investments in Ukraine.[1] Its capacity far exceeded the needs at that time and have not been fully used before 2007.

After the Yamal pipeline was completed, relations between Russia and Belarus have spoiled and followed the same path as with Ukraine. In response Russia abandoned all plans to modernize the system in Ukraine or to build a second pipeline along the Yamal track and chose a new export route instead. Recently, it initiated the construction of a large offshore pipeline - the North European Gas Pipeline, also known as Nord Stream. The pipeline will stretch through the Baltic sea and connect Russia directly to Europe bypassing all the transit countries. The new project is by far the most expensive of all options.[2] It is at least four times more expensive than the upgrade of the Ukrainian system and twice as expensive as the second pipeline through Belarus.

The observed investment pattern considerably deviates from "non-strategic" investment, which would maximize the profit of the entire network and minimize transportation cost. Investments, to a large extent, reflect the desire of Russia to gain an advantage in bargaining with the transiters. In this thesis we analyze the strategic distortions of investments and study how

[1] The author is thankful to Frank Tauchnitz and his assistants for data about investment costs for pipeline projects, although some data can be also found on the websites of the projects themselves, e.g. Europol Gaz about Yamal Project see http://www.europolgaz.com.pl.

[2] For more detail see http://www.nord-stream.com/ .

investments may alter the power structure in the Eurasian supply chain to provide a rationale for the developments in the network.

Production and transportation of natural gas are characterized by large up-front investment costs, most of which are sunk after capacities are installed. Building a pipeline requires international cooperation among the countries, whose territories the pipeline will pass. The parties of the supply chain have to form a stable coalition in order to coordinate investment and agree on long term rent sharing. Within the EU there acts an established legal system, built on a number of Treaties, to enforce property and contract rights. In particular, the EU members signed the Energy Charter Treaty - an international agreement, which regulates and adds credibility to energy trade, transit and investments within Europe. However, at present there is no international court system established to enforce gas transit contracts within FSU and hence, there is a risk of ex post opportunism. Once investments are made, transit countries enjoy a much increased bargaining power. If they cannot credibly commit to stick to a long-term agreement on profit sharing, other countries will anticipate a strategic abuse and distort their investment. Thus, disputes with Ukraine and Belarus highlight a commitment problem, which causes strategic distortions in Russia's investment.

As the gas demand in Europe is growing other FSU producers intend to enter the European market. The Caspian Republics can export as much gas as Russia does and do so at lower costs. Currently the Caspian producers can reach the European market only via Russia. Unable to market their gas directly, the Caspian producers have been forced to sell their gas to Russia at low prices. However, with the support of the USA and the EU the producers have developed plans to bypass Russia. The USA have offered its help to build a Trans Caspian pipeline passing through Azerbaijan, Georgia, and Turkey. The EU has suggested an alternative route across Iran and Turkey - the Nabucco pipeline. Both projects are expensive, with transportation costs significantly exceeding the costs of transit through Russia. Progress has also been slow due to the difficult political situation in the region. Nevertheless, the installation of pipelines had been made. A Georgian section of the pipeline connecting Turkish border with Azerbaijan is close to completion. Turkmenistan and Iran have a tentative agreement to raise financial capital to proceed with the pipeline.

The formation of a competing supply chain will reduce Russian profits. This kind of externalities strengthen the bargaining position of the Caspian players. Russia has already made substantial concessions to the Caspian producers to prevent the construction of the alternative pipelines. It has contracted a large increase in gas imports and agreed to much higher prices for Turkmen gas. In this thesis we address the interrelated issues of strategic investments, coalition formation, and bargaining in vertical supply chains with externalities. We provide a framework to understand the developments of the relations between Russia and the Caspian Republics.

As in the case of Ukraine and Belarus, the investments in the Caspian pipelines will give the transiters, Azerbaijan and Iran, a strategic advantage. As a result the hold-up problem arises. In our work, we analyze how the Caspian transiters' inability to commit will affect investment and predict whether the pipelines will finally be built.

The thesis is divided into four chapters. In chapter 1 we describe the Eurasian gas supply system. We characterize the main players, review the past investments and future pipeline projects. Besides, we provide details of the conflicts among the countries involved in the gas supply and examine the prospects for Russian and Caspian gas trade. In the second part of chapter 1 we explain the quantitative assumptions on the parameters of demand and supply for the FSU gas and investment costs of pipeline projects. As the technology of gas production and pipelines is well known, we are able to estimate production, transportation, and investment costs of gas supply with reasonable accuracy to calibrate our theoretical models. We collect a fair body of data about the past, present, and future gas consumption in Europe, that enables us to make sensible assumptions on demand.

In chapter 2 to 4, we analyze the Eurasian gas supply network from three different perspectives. Chapter 2 is based on the joint work with Franz Hubert. In this chapter we look at past distortions of investments in the Eurasian gas supply network. At that time the Caspian producers had no access to the market and shut down their gas production almost completely. Therefore, to simplify the analysis we do not take the Caspian Republics into consideration and focus instead on the interactions of Russia, Ukraine, Belarus, and Poland. We use a two stage multilateral bargaining game among heterogeneous players, some lacking the ability to make long-term commitments, to analyze the situation. At the first stage the players negotiate contracts over access rights and investments. At the second stage investment costs are sunk, capacities are given and the players bargain about the sharing of rents from previous investments. We apply the solution concept by Owen [1977], which is an extension of the Shapley value (Shapley [1953]), to model bargaining and we use the approach by Segal [2003] to analyze access contracts. Our qualitative and quantitative analyses provide an explanation for overinvestment in the pipeline through Belarus and Poland and through the Baltic sea, and underinvestment in Ukraine's transport system. Overinvestment results from an attempt to create countervailing power.

In chapter 3 we analyze the current situation in the network. We extend our analysis and add the Caspian Republics to the list of players, but we exclude Poland, because as a EU member, it has a limited ability to behave strategically. We address the problem of endogenous coalition formation and multilateral bargaining in the presence of externalities, which result from the possibility to form competing supply chains. Again we derive the power structure in the Eurasian gas supply network deriving it endogenously from the architecture of the network. However, we neglect possible commitment problem and do not consider strategic investment decisions. We use a model based on a game in a partition function form introduced by Thrall and Lucas (1973). To solve the game we apply a solution recently proposed by Maskin [2003]. Our quantitative analysis shows how the bargaining power changes depending on pipeline options. We also find that investment options affect the incentive to cooperate resulting in different equilibrium coalition structures. The results allow us to explain the recent price concessions of

Russia to the Caspian producers.

Finally, chapter 4 combines the analysis of chapters 2 and 3 to predict the future developments in the Eurasian gas supply network. In chapter 4 we consider the prospects for Russian and Turkmen gas supply assuming that some players can not commit to long-term contracts. We study how the "hold-up" problem affects coalition formation and strategic investment in an environment with externalities. We again use a two stage model. At the first stage, players form coalitions to invest cooperatively and agree on the future rent sharing. At the second stage, network capacities are given, investment costs are sunk, the players form coalitions to supply gas to the market in the framework of contracts signed at the first stage, and bargain over profits sharing. The two stage setting resembles the model by Kreps and Scheinkman [1983], since we assume a capacity choice on the first stage and price competition on the second. To find the outcome of the bargaining we apply a concept proposed by Maskin [2003]. Based on the quantitative analysis we observe that anticipating future renegotiations with unreliable players, players will distort their investments. In equilibrium underinvestment as well as overinvestment occurs as the result of the "hold-up". Moreover, the lack of ability to commit by producers might lead to formation of competing supply chains. We succeed in explaining why Russia invests in an expensive pipeline through the Baltic see, and why the expensive bypass pipelines via Azerbaijan and Iran may be built. Besides, we show under which contingencies Russia and the Caspian producers will cooperate and under which competing supply chain will form.

In all those analytical chapters we calibrate the models with reasonable accuracy to derive quantitative results which can be compared with real world data. Hence, the European gas network provides a rather unique opportunity to confront advanced game theoretical solutions with real world experience.

Although the results of our analysis fit the reality quite well, there are a number of limitations which lead to some discrepancy with the real world figures. Hence, several issues are left for further research. First, we do not explicitly model the interaction of the FSU gas producers with other exporters at the European market, such as Norway, Algeria, and African and Middle East supplies of liquified natural gas. Rather, we model the European market non–strategically and simply estimate a residual demand for gas from the Former Soviet Union. Second, in our study we focus on relationship of producers and transiters only. However, in reality major European importers, like French monopoly Gas du France, German giants E.ON and Wintershall, or Italian Eni. do take an active part in investments in pipelines. Hence, a natural extension of the models would be to include gas importers into the investment game. Third, all three models presented in the thesis are static by their nature. We assume that the players make investment decisions and negotiate cooperation once and for all. Hence, we do not account for the dynamics of repeated interactions. In the absence of an international enforcement system long-term cooperation can be sustained by mutual threat of retaliation in future periods. This type of dynamic cooperation, referred to as collusion, is explored in the literature on cartels and can be applied to the Eurasian gas network. Our fourth restriction concerns the players' ability to commit. In the course of our analysis we consider only extreme cases assuming that players either can commit or not. Alternatively, one could assume that players renegotiate with some probability.

Chapter 1

Description of the Eurasian Gas Network

1.1 Players and investment options

In 2005 natural gas had a share of 25% in the fuel mix of the energy consumption of the European Union.[1] This share is likely to grow as gas is considered to be an environmentally friendly source of energy. At present more than 55% of the gas consumption in Europe is covered by external producers. The major players in the European import market are Russia with an approximate market share of 40%, Algeria with about 25%, Norway with about 30%, and African and Middle Eastern countries, providing liquified natural gas (LNG), have slightly more than 5% (see Figure on page 25). The demand for gas in Europe is growing, while domestic gas production is declining. As a result, by 2015 the contribution of external suppliers will increase to over 65%.[2] Norway, Algeria, and LNG suppliers are not able

[1] For the European gas consumption and gas import figures see British Petroleum (2005) Statistical Review of World Energy.

[2] Commission [2005] Green Paper, Para 1; Agency [2003], Table 4.2, p.140

to raise their production substantially and will satisfy only 55% of the gas imports, see e.g. de Vivies [2005]. To meet the residual demand EU relies on gas from the Former Soviet Union (FSU), in particular Russia and gas producers of the Caspian Basin.

European countries buy gas by "take-or-pay" contracts, typically ranging from 15 to 25 years.[3] These long-term contracts are signed between a producer and a buyer: the former commits to steady deliveries of a certain quantity of gas, the latter is obliged to pay for that quantity whether it is taken or not. Historically, the point of delivery is considered to be the Western European border. Hence, producers have to also tackle the transportation issues, namely transit relations and coordination of investments in transport capacity.[4]

The increasing dependency on FSU gas exports raises a number of concerns, including security and reliability of gas supplies. Russia has always fulfilled its export obligations to European partners. It developed a reputation of being a reliable partner during the Soviet time and maintained its reputation after the Soviet Union collapsed. It is also worth saying that the dependency is mutual as Russia heavily relies on profits from gas export. Currently, the reliability problem mainly refers to security of gas transit. For the delivery of its gas to European consumers, Russia depends on the Former Soviet Republics - newly independent countries, e.g. Ukraine and Belarus,

[3]So called 'take–or–pay' contracts regulated prices and quantities to ensure the efficient usage of the capacities and steady revenues. To account for changes in the economic environment gas prices used to be indexed to oil prices. However, over a long period of time the contracted quantities had to be paid for whether used or not, hence, the name 'take–or–pay' (Asche et al. [2000]). As the gas market developed, prices gained some independence from oil prices and the current drive for liberalization favors short–term contracts and third party access. In spite of these changes, it is still common that producers and importers form consortia to realize new projects under long–term agreements (Stern [2001]).

[4]Although gas buyers often contribute investment capital, they stay away from the supply and transit issues as such. See "Energy Information Administration" on Administration [2002] for more information on international pipeline investment projects.

with whom it has failed to build long-term stable relations. The European Union does also not have a sound political or economical leverage on non-EU transiters. There are also no international institutions established to resolve transit conflicts or enforce multilateral contracts. Therefore, disputes are to be resolved through bargaining.

In what follows we describe the main features and conflicts in the supply chain for FSU gas, which hereafter we will refer to as the Eurasian gas network. We start with the current players of the network and sketch their conflicts, then proceed with the characteristics of players, who may join the network in the near future.

1.1.1 Current players

The Eurasian gas network was mainly shaped in the late 70s, when the Soviet Union started exporting gas to the European market. At that time a system of pipelines was built running through territories of Ukraine and Czechoslovakia and connecting to internal gas systems of Austria and Germany. When the Soviet Union collapsed, Russia found itself in the uncomfortable position with its only supply route to Western Europe passing through three newly independent states: Ukraine, Slovakia and the Czech Republic. Looking westward towards integration with the EU, Slovakia and the Czech Republic privatized their transmission pipelines. The Slovakian section was acquired by the German Utility RWE, the Czech section by a consortium of Gazprom, Ruhrgas and Gaz du France. Since yielding control over pipelines to the importers, the countries never attempted to use their strategic location as a bargaining chip in negotiations with Russia.

In contrast, relations between Russia and Ukraine turned sour. In principle, Russia pays for transmission by supplying gas to Ukraine, approximately 26-30 bcm/a (plus an additional 6-7 bcm/a compressor gas).[5] This payment in

[5]Hereafter we use conventional units for gas, i.e. billion cubic meter a year = bcm/a.

kind is sometimes translated into a ‘transit fee’ by assigning a price to the gas. Besides the quantities of gas delivered by Russia for transit, Ukraine needs additional 20 bcm/a. The conflict has essentially evolved over the compensation for this extra gas, which Ukraine could hardly pay for. While Russia claimed average European prices, Ukraine admitted only half of that. However, even this lower price has not fully been paid. As a result debts accumulated. In 2002, these amounted to $ 1.4 bn, or $ 2.3 bn, depending on which side one takes.[6]

As the dispute about non–payments for gas deliveries and debts dragged on, Russia tried to reduce its supplies to Ukraine. In response the transiter syphoned off gas from Gazprom’s storages on its territory and from European export pipelines. Russia has little choice but to supply whatever Ukraine takes or to default on its obligations to western importers. Although Ukraine’s withdrawals interrupted gas supplies to Western Europe only occasionally for short periods, these episodes highlighted Russia’s vulnerability and threatened to taint its reputation as a secure supplier.

Meanwhile, in late 90s the capacity of the Ukrainian transmission network, which we will name $Ukold$, dropped to 70bcm/a due to aging compressors, lack of maintenance and underinvestment. The cheapest and fastest option to increase export capacities would be to upgrade the Ukrainian system. By replacing old compressors the transmission capacity could easily be increased by 15 bcm/a. Hereafter, we will refer to this possibility as *Upgrade*. In 2002 Gazprom and Ukrainian Naftogas reached a tentative agreement according to which Russia in co–operation with German Ruhrgas would attract $ 2.5 bn to upgrade the system.[7] Ukraine in its turn should have given the investors a control stake over the transit system. However, after Ukraine refused to sell the required package of shares, Russia declined to invest in Upgrade.

Instead, as a direct threat to Ukraine’s strategic position, plans have been

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[6] For further detail see news [2000].

[7] Commission [2000–2007].

drawn up for a twin–pipeline going to Germany through Belarus and Poland. In 1994 Russia started the project often referred to as *Yamal*.[8] Initially Yamal included two pipelines with total capacity of 56bcm/a. Eventually, only the first export line, so called *Yamal 1* was installed. In the late nineties this pipeline with a potential capacity of 28 bcm/a had compressors to support only 18 bcm/a and reached its planned level only in 2006. Together with the first pipeline, at major river–crossings pipes for the second band, *Yamal 2*, have been laid.

To manage the transit through Yamal in Poland a joint stock company, EuroPolGaz, was established in which Polish PGNiG and Russian Gazprom hold equal shares. In 2004 Poland became an EU-member and since then its transit obligations can be enforced by the European legal system. Russia and Belarus agreed on a long–term solution for sales and transit relationships, including the transfer of the assets of Beltransgaz, Belarus' national gas company, to Gazprom under a 99–year lease. In exchange, Russia would have increased gas supplies to Belarus, which like Ukraine, buys Russian gas for its domestic needs at a special price. Yet, the Belorussian parliament did not ratify the agreement. Thus, Russia failed to gain control and to guarantee security of its export via Belarus. Instead, it again found itself in a weak bargaining position.

After the dissolution of the Union, Belarus' ties with Russia remained very close and its ability to act independently was fairly restricted due to its weak economy. The country had to rely on subsidies from Russia in the form of reduced prices on a bundle of goods including gas. However, even in this situation Belarus accumulated significant debts. Shortly after the pipeline was installed, Belarus start exploiting its strategic position in financial disputes with Russia. Every attempt of Russia to raise the gas prices has resulted in

[8] The name came from the idea to connect this pipeline to a large gas field in the Yamal peninsular. As demand was weak during the nineties the project was gradually scaled down. The development of the field was postponed. Only the section of the pipeline, from the Russian border to Europe, was to be built. See the extended description and the complete history of the project in Stern (2005).

renegotiations over the proportional increase in transit fees. When Russia cut off gas supply to Belarus in February 2006, the transiter took the required gas from export pipelines. To fulfil its export obligations Russia had to compromise and restored the delivery. A number of short-term agreements were produced to settle the feuds, but little progress was made to find a long-term solution. Just recently, on 31 December 2006, a new long-term contract was signed. It doubled gas prices for Belarus from 47$/tcm to 100$/tcm, which is still just a half of the price Western Europe pays, and envisaged a stepwise adjustment to international prices by 2011. However, the increase in prices is partially compensated by a 70% increase of transit fees and by cash payments, Gazprom is expected to make for the acquisition of Beltransgaz (see Yafimava and Stern [2007] for details). Given Gazprom's past failures in attempts to gain control over transit pipelines, it is very likely that Belarus may again fail to implement the last step and Gazprom's payments would mainly offset the price increase.

Increasing frustration with the demands of transit countries led Russia to look for a direct, though much more costly, offshore option. The pipeline, known in 2000 under the name of North-Trans Gas and later called the North European Gas pipeline (here *NEGP*), or Nord Stream, has been designed to carry Russian gas through the Baltic sea directly to the German border. The project was initially under the control of the German-Russian consortium of Gazprom, Wintershall, and E.ON-Ruhrgas. Investment costs of this offshore pipeline are at least twice as high as any onshore pipelines, and NEGP has long been regarded as unfeasible, nevertheless, Russia started work on the offshore section of NEGP in 2005. Originally planned capacities were from 18 to 30 bcm/a, but the new scale of the project is 55bcm/a.[9]

Several observations are particularly notable in this context. First, the transiters, Belarus and Ukraine, failed to establish long-term stable relations with Russia. They are involved in continuous bargaining over compensation for transit and for import of Russian gas. The renegotiations highlight

[9]http://www.nord-stream.com

the commitment problem. As the result investments suffer from the hold-up problem. Second, despite the conflicts, interruptions to Russian supply have been very rare and short. As a rule, the players bargain and use their capacities efficiently. Third, we note that Russia's choice of investments reflects the desire to strengthen its position, rather than investment costs. However, while the capital costs of investment projects are known, the strategic gains can not be estimated directly. In the following chapters we develop an approach to quantitatively assess the strategic value of investment options.

1.1.2 Prospective players

During the Soviet time, Russia and other Republics consumed a significant amount of gas from Caspian Republics, of whom the largest gas supplier was Turkmenistan. Turkmen gas, together with Russian gas, was also sent to the European market. After the collapse of the Soviet Union, the Caspian producer demanded "world prices" for their gas, but the FSU countries were not able to pay that price. Then, Turkmenistan stopped the delivery to its former customers hoping to receive profit from export to Europe. However, all the export routes from the Caspian fields to Europe run through Russian territory. In the 90s gas demand in Europe shrank. To secure its own export revenues Russia denied potential rivals' access to its pipeline system. As a result, gas production in Turkmenistan dropped from 84bcm/a in 1991 to 13bcm/a in 1998.[10]

With no other options to market its gas Turkmenistan had to agree to supply Russia and neighboring countries for a price almost three time lower than that paid by Europe.[11] The largest consumer for Caspian gas was Ukraine. Turkmenistan had to meet Ukraine's demand not covered by gas import from Russia. However, when Ukraine was unable to pay for its import,

[10]See gas production statistic in Stern [2005].

[11]Until 2005, Turkmenistan obtained 44$/tcm for its gas. As Ukraine agreed to pay more for Russian gas, the payment to the Caspian producer rose to 65$/tcm. At present, the price agreed with Russia is 100$/tcm, whereas Europe pays more than 200$/tcm.

Turkmenistan simply cut its deliveries. This move put Russia into troubles, as Ukraine threatened to take gas from the export pipelines. In 2004 Russia signed an agreement with Turkmenistan to buy its gas for Ukraine to relieve itself from the increased burden.

The terms of the cooperation between Russia and Turkmenistan, however, are highly dependent on the outside options of the Caspian producer. After 1997 the demand in Europe recovered and entered a phase of steady growth. Producers of the Caspian region again turned an eye on the European market. After keeping their fields idle for the last decade, they can easily raise the extraction since fields are developed and equipment is in place. The milder climate conditions of Caspian fields give them a cost advantage compared to most Russian fields situated in the permafrost terrain. All this makes Turkmenistan, which can cover up to 80% of Russian export, a potentially strong competitor in the European market. But to reach the European market, the Caspian producers will have to bypass Russia.

At the beginning of the century, the USA and the EU proposed several projects with the intention to abate the dependency on the Russian gas supply and enhance the opportunity for the Caspian producers to access the European market. The USA offered its support to the Trans-Caspian Pipeline, to which we will refer as TCP. The project was first proposed in 1999 to supply 30bcm/a of Turkmen gas to Turkey across the Caspian sea and Azerbaijan. However, while Turkmenistan and Azerbaijan were arguing over a transit contract, Russian Gazprom accelerated its own negotiations with Turkey. As a result, Russia contracted to supply 16bcm/a of gas and started building the Blue Stream pipeline to supply its gas to Turkey through the bottom of the Black sea. A key partner in the construction of the pipeline was Italian gas monopoly Eni, who's intentions were to extend the pipeline further to deliver gas via Turkey to Italy. In 2003 when the USA suggested to build a pipeline bypassing Russia, the TCP project was revised and extended. The new plan was to export Turkmen gas via Azerbaijan and Georgia to Turkey and further to Italy and through Bulgaria to Austria.

In December 2006 Baku-Tbilisi-Ceyhan pipeline, the Georgian section of TCP connecting Turkish system with Azerbaijan, start delivering Azeri gas to Turkey. The growing US influence in the region made Georgia look like a reliable transiter. However, the project still faces a number of difficulties. The Nagorno-Karabakh conflict complicates installation of the pipeline and its security in Azerbaijan. The country has a tight budget and can hardly pay investment costs up front. The unstable position of the country complicates the attraction of the financial capital from outside. Besides, as before Azerbaijan and Turkmenistan stalled on a transit deal. Turkmenistan agrees to give up one third of supply profit on account of transit, yet Azerbaijan insists on at least a half. Taking into account the history of the dispute one can assume that it may take a long time to reach a compromise.

Sceptical about the result of these negotiations the European Union favors an alternative pipeline running through Iran to Turkey and further to Europe. However, this pipeline, which we will refer to as *Nabucco*, also faces obstacles. Iran holds huge gas reserves and seems to be interested in the project for itself. Although it is ready to pay up front for its part of the pipeline and readily agrees on terms of a transit deal proposed by Turkmenistan, it seems very likely that it would like to use the existing capacity for its own supply. A pipeline connecting the Nebit Dag, Korpedze and Okarem fields in Turkmenistan with the internal Iran grid at the Kord-Kul node was already launched in 1999. Currently it delivers less than 10bcm/a to Iran, but the plan for the additional 20bcm/a with a further connection to Turkey has already been outlined. However, it is unlikely that the project will be implemented without Turkmenistan, therefore Iran has to agree with a role of a transiter.

Some concerns regarding the Caspian pipelines have also been raised against Turkey. The country is located at the crossroad between Caspian and Middle East Countries. As the gas flow to Europe was growing, Turkey became ambitious to establish itself as an exporting country.[12] There is a chance,

[12]Turkey imports Russian gas through the Blue stream pipeline in the Black Sea. The

that once the pipelines are completed, Turkey would recontract to change its role from a transiter to the role of an exporter. At the same time, however, the country is looking forward towards its joining the EU. Hence, Europe has some leverage over Turkey, which might be pushed to sign the Energy Treaty, the agreement obliging its members to undertake a third party access to transit facilities. In this case Turkey would not be permitted to compel a resale contract from Turkmenistan. In view of this argument, it seems more adequate to assume that Turkey will be held back, so that the Caspian producers can rely on the access to the transit capacities.

Despite all the problems, the Caspian pipelines present a viable threat for Russia. First, it may lose the inflow of low cost Caspian gas[13] and will have to develop new fields sooner, significantly increasing the supply costs. Second, if Turkmenistan enters the market, Russia will meet a stronger competition and lose a part of its export profits. In view of the competition and its negative impact, Russia complied with demands of Turkmenistan in recent negotiations over the export price on Turkmen gas. In 2005 Turkmenistan enjoyed a 20% increase in prices from 44$/tcm to 56$/tcm and in 2006 the price jumped to 100$/tcm. Russia also contracted a drastic increase of Turkmen export volumes from 30 bcm/a in 2006 to 80 bcm/a in 2025. These concessions dampened Turkmenistan's interest in the alternative routes. At present it looks as if the bypass projects have been postponed.

To conclude, it is worth mentioning a few issues related to the Caspian players. First, we note that if Turkmenistan succeeds in forming a coalition with Iran and/or Azerbaijan, a competing supply chain will form. Competition will reduce profits of Russian gas supply and weaken the strategic position of Russia. We will refer to this negative effect as an "externality". In chapter

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amount of gas contracted leaves Turkey with 6-8 bcm/a of excess gas. Recently, Turkey won the right to sell excess gas to Europe. Together with 5bcm/a of Iranian gas and over 20bcm/a of Turkmen gas, Turkey may export up to 30bcm/a.

[13]At present, fields in Siberia are at peak production or in decline. To increase its export Russia has to develop new fields on the Yamal peninsular. This requires significant investments and will raise the supply cost of Russian gas.

3 we address the bargaining and coalition formation issues in the presence of externalities and derive the strategic value of investment options. Second, by analogy with the Russian supply chain, the lack of enforcement of transit contracts between Turkmenistan and its transiters, results in the hold-up problem. In chapter 4 we study how the ability to commit may affect future development of the Eurasian gas supply network.

1.2 Quantitative Assumptions

In the next chapters we will have to calculate profits of gas supply under various assumptions on available pipelines and investment options. These profits depend on assumptions on demand and supply functions and on investment costs of the pipeline projects. In this section we introduce different quantitative assumptions used further in our analysis.

1.2.1 Demand

The market, we have in mind, is represented by the core members of the European Union – EU15, who's share in total European gas consumption is over 90%.[14] We refer to these countries as Western Europe. The import demand of Western Europe is covered by Algeria, Norway, LNG suppliers, and the Former Soviet Union. The demand for FSU natural gas depends on preferences for natural gas, the prices of other exporters and substitutes such as oil and gas from competitors, preferences for diversifying energy supply, the cost of transporting gas within Western Europe etc. Unfortunately, data on gas prices and consumption in Western Europe are too poor to allow a thorough econometric estimation. The bulk of the deliveries is under a small

[14]EU15 includes Austria, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, Switzerland, and the UK. We look at the market formed by these countries as a whole, without specifying demand for each individual country.

number of long–term contracts, the details of which are not made public. Available data on gas prices largely reflect oil–price movements. They are of little relevance for the buyers tied up in these agreements. Moreover, many of the important structural determinants of demand for FSU gas, such as environmental concerns, preferences for diversity of supplies, turbine technology etc., are changing fast. For simplicity, we use a linear demand function.

In the following chapters we take three different time perspectives on the European gas market: "past", which refers to the situation in the late 90ies, before Yamal 1 went into operation; "current", which refers to the situation around 2005, and "future", which reflects expectations for the next decade in 2015. For each scenario we derive demand and supply separately. Since there is substantial uncertainty about demand as well as supply costs, we make 'sensible assumptions' to calibrate the model. We use information on supply cost of non–FSU gas suppliers provided in de L'Energie [2002] and Kommission [2001] to estimate a range of parameters for the residual demand for FSU gas.[15] As discussed in the previous section to satisfy the demand in the late 90s it would be sufficient, to upgrade and renovate the Ukrainian transport system. Hence, for "past" we choose the parameters of the demand so as to make the existing 70bcm/a in Ukraine plus 15bcm/a of Upgrade be optimal for the network formed by Russia, Ukraine, Belarus, and Poland (see Hubert and Ikonnikova [2003] and Hubert and Ikonnikova [2004]). This gives us the intercept of 160 and the slope of 0.35. The resulting price of 125 $/tcm (thousand cubic meters) roughly coincides with the average market price in 2000.[16]

To describe "the current situation" we take the demand parameters under which the existing capacities along Ukraine and Belarus, i.e. 70bcm/a of Ukold and 28bcm/a of Yamal 1, maximize the profit of the coalition of Rus-

[15] The detailed description of how we derive the residual demand function is provided in the Appendix A.

[16] Through our analysis we focus on wholesale gas prices at the European border, treating Europe as an integrated market.

sia, Belarus, Ukraine, Turkmenistan, Azerbaijan, and Iran. In this case we find the intercept of 175 and the slope of 0.40. Finally, looking forward into the next decade we adjust the demand function as to obtain 40 bcm/a increment in supply. This is the amount by which Gazprom plans to increase its export deliveries to Western Europe according to Intelligence [2003]. About 20bcm/a of this amount has already been contracted by France. The rest is expected to be demanded by the other EU15 countries, mainly by Germany. We estimate the residual demands for FSU gas with the intercept in the range of 250 to 230 and slopes of 0.4 to 0.3 that yields an approximate price of gas about 195 $/tcm.

1.2.2 Supply

Costs of supply consist of production and transportation costs. Production cost account for gas extraction and depend on terrain, climate conditions as well as infrastructure in place. The costs vary with fields and are specified for each producer individually. We assume a linear increasing function for the average production cost $ac_i(q) = m + c \cdot q$, we use the subscript to refer to the producer. Production costs tend to increase as production from old low cost fields declines and new, more expensive fields have to be developed. Hence, we again derive different functions depending on a time frame.

In the 90s the devaluation of the rouble led to a drop in fixed cost of Russian production evaluated in dollar to about m_r =11$/tcm according to of USA [2002] and Agency [2003]. After 2000 the growth of domestic as well as of European gas demand led to increases in production. Old fields, like Medvezhye were in depletion and new gas fields have to be tapped. The costs of production from recently developed fields such as Zapolyarnoye are estimated in the range of 20 to 30 $/tcm (Bank [2005]). The cost of m_t =20 $/tcm can also be taken as a "sensible" figure for gas production in Turkmenistan. In "The strategy for the Russian gas industry development" Gazprom [2003] it is suggested that the costs of Russian gas may increase up to 40 \$/tcm, if fields like Stockman or Yamal have to be developed.

Further, according to scenarios of Russia energy sector development presented by Bank [2005], we estimate the slope of the production cost function for Russia as c_r=0.4. For Turkmenistan Mavrakis et al. [2006] provide data which give the slope of production cost for Turkmenistan c_t=0.35.

Transportation costs account for operation costs and gas losses. These costs depend on the length of a pipeline and specific features of the track. The operation costs consist of expenses on management and maintenance of pipelines and compressor stations m and gas losses g, that is the per cent of gas utilized by compressors on pumping to keep the pressure in pipelines. Costs grow with the supply distance d. For the onshore pipeline the loss factor is $g = 0.25\%$ of gas per $100km$, for the high pressure underwater pipelines the figure is doubled $g = 0.5\%$.[17] The maintenance costs also differ for onshore and offshore pipelines. Here we assume $m = 0.1\$/tcm{\cdot}100km$ and $m = 0.2\$/tcm \cdot 100km$, respectively.[18]

The total cost of gas supply includes both production and transportation costs. For our analysis we derive a simplified formula of the total cost of supply. We take that the costs should include all the expenses on the way, namely gas consumption by compressor stations and operation costs.[19]

[17]See Oil, gas and coal supply outlook (1995) for further explanations of the transportation technology.

[18]Maintenance costs are estimated based on operation costs details provided by Frank Tauchnitz (Wintershall).

[19]With every additional 100km the expenses increase due to gas consumption by compressor stations and maintenance costs that we express as follows:

$$\frac{tc(q, d + \triangle) - tc(q, d)}{\triangle} = m + g \cdot tc(q, d) \tag{1.1}$$

Taking the limit, we obtain a differential equation. We solve the equation given that supply costs at the source ($d = 0$) are equal to the production cost. For further details see Hubert and Ikonnikova [2003].

Then, we obtain:

$$tc(q) = ((\frac{m_l}{g_l} + ac_i(q))e^{g_l \cdot d_l} - \frac{m_l}{g_l})q_l, \quad i \in \{r, t\}. \tag{1.2}$$

Note, transport cost parameters are specified for each pipeline l.

As we express all figures on an annual basis, we also annualize investment cost, which are usually given in total. We use the following formula: $I_i = \frac{r \cdot \bar{I}_i}{(1-(1+r)^{-t})}$, where $\bar{I}_i$ is the total investment per capacity. We take the real interest rate for investment to be $r = 0.15$. The lifetime of pipelines is taken to be $t = 25$ years.

We distinguish two types of investment projects: projects to increase capacity of an installed pipeline and projects to build a new pipeline. The first type of projects include installation of extra compressor stations and can be completed within months. As for a new pipeline, it might take two or three years, before the pipeline goes into operation and can deliver gas. To take this delay into account we inflate the investment cost of new pipelines by 15%.

Table 1.1: Description of the links

Link	max capacity k_l[bcm/a]	invest. cost I_l[$/tcm]	distance d[100km]	supply cost tc(1tcm)[$]	countries, forming a supply chain
Ukold	70	sunk	16	17.2	Russia, Ukraine
Yamal1	28	16.1/sunk	16	17.2	Russia, Belarus
Upgrade	15	7.7	16	17.2	Russia, Ukraine
Yamal2*	∞	15.2	16	17.2	Russia, Belarus
NEGP*	∞	24.9	16	17.2	Russia
TCP*	30	23.7	38	15.0	Turkmen., Azerb.
Nabucco*	30	23.7	38	15.0	Turkmen., Iran

Table 1.1 gives the aggregate figures for supply and investment costs for the investment options under the consideration. The figures for supply costs are calculated for the total supply of one thousand cubic meter of gas. In the table we mark with a star new pipelines, for which we inflate the values. The first two rows of the table describe the existing pipelines in Ukraine

and Belarus. Their capacities are fixed and investment costs are sunk. But if we look backwards to when the first Yamal pipeline was built we find that the investment cost of Yamal 1 was equal to 16.1$/tcm. The next two links are the extension of the first two pipelines: Upgrade of Ukrainian pipeline system and the second Yamal pipeline. These two investment projects are the cheapest investment options, as one may see from the second column of figures.

The second column shows that we limit the capacities of investment projects TCP, Upgrade and Nabucco. To install capacity over the given limits, one would need to invest in the extension of the connected transmission network, i.e. the pipeline system in East Europe and Turkey. New players will be involved and supply costs of the unit of quantity delivered to the market will soar. In contrast, the Yamal 2 and NEGP directly join with the European gas network. Europe is assumed to adjust the internal grid to the import needs on its own, so no restrictions are put on the pipelines going directly to the EU border or owned by the EU companies. We assume the length of all the pipelines delivering Russian gas to be roughly the same. It is true for all the pipelines except for Ukrainian system, which is about 400km longer. Hubert and Ikonnikova [2003] have checked that this assumption does not lead to significant change in results, while allows us to avoid additional complexity in calculations.

tex

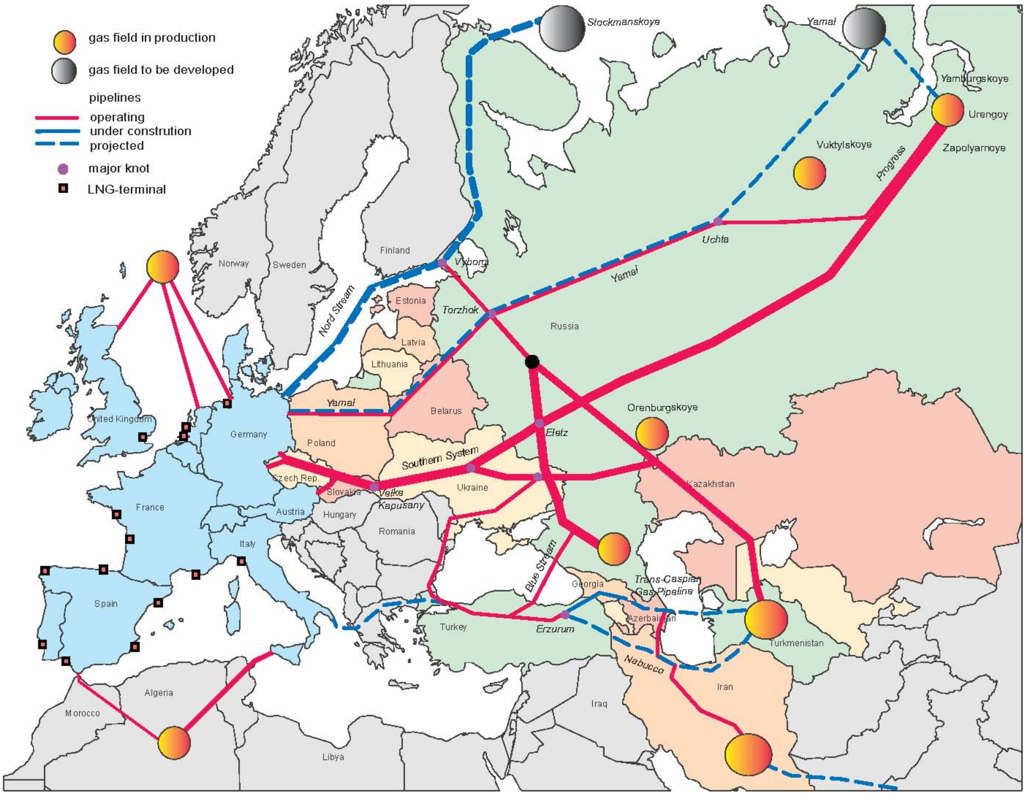

Figure 1.1: The Eurasian gas supply network.

Chapter 2

Commitment and access rights

2.1 Introduction

In this chapter we analyze the development of the Eurasian gas supply network in the nineties. At that time, for the delivery to the lucrative markets in Western Europe, Russia depended entirely on transit through the newly independent Ukraine. However, plans to upgrade the old Ukrainian system, which would have been the cheapest way to satisfy a sluggish demand, never got off the ground. Instead Russia designed two projects: the Yamal pipeline, running through Poland and Belarus and the North European Gas Pipeline - a direct link through the Baltic sea. After succeeding in negotiations about control rights over the sections of Yamal in Poland and Belarus, Russia started building the pipeline. The project of the offshore pipeline through the Baltic sea was postponed. However, in view of disputes with Belarus, which started shortly after the first deliveries through the Yamal pipeline, Russia turned back to the offshore pipeline and began building NEGP in 2005.

The purpose of this chapter is to shed light on the past developments and answer the following questions: Why did more expensive Yamal was preferred to the project on upgrading the Ukrainian system? Why did Russia first choose Yamal, but then initiated NEGP?[1]

As discussed in chapter 1 the dissolution of the Soviet Union raised the issue of security of gas supply, which is closely related to the issue of who has strategic control over transit pipelines. Intuitively, plans for new pipeline connections reflect to a large extent Russia's desire to strengthen its bargaining position vis-á-vis transit countries by diversifying its transport routes. Investments in pipelines generate large quasi–rents. In this case the ability to credibly commit to the long-term profit sharing is crucial. In the case of recontracting, a player's bargaining power is increased if he is in de facto control of transport capacity. In principle, a player can be asked to pay up–front for the increased bargaining power at the investment stage. However, large up–front payments are not feasible for the FSU players. The cash–strapped countries cannot afford to compensate others for their future gains in bargaining power. The lack of international contract enforcement, financial constraints and limited commitment result in the hold–up problem.

To study strategic investments we use a two stage multilateral bargaining game, with Russia, Ukraine, Belarus, and Poland being the major players. At the first stage the players form coalitions, negotiate contracts over access rights and invest in transport capacities. At the second stage investment cost are sunk, capacities are given and the players bargain about the sharing of rents from the previous investments. We assume that contracts at the second stage are complete with respect to prices and quantities. As the number of players is small and the basic technologies of gas transport are well–known, the members of the Eurasian supply chain are assumed to bargain efficiently and to make the best use of the existing transmission capacities. This allows us to use the Shapley value, a well–known solution concept for multilateral

[1] As it follows from Section 1, the Caspian producers did not appear on the stage at that time.

bargaining, to calculate the sharing of profits in the supply chain. The relative size of payoffs indicates the strength of the players' positions. Hence, we derive the bargaining power of the parties in a very natural way from the features of the transmission grid.

As to investments at the first stage, however, it is not always possible to write credible long–term contracts to prevent recontracting. Otherwise, bargaining over rents would never occur because everything would be stipulated in advance. We assume that players are heterogeneous in the sense, that some can credibly commit to comply with obligations in the future, while others will recontract if it is in their interest to do so. Russia, for example, has worked hard to establish a reputation for reliability in the gas market for almost three decades. It would lose its reputation if it defaulted on its obligations to achieve short run gains. Poland was heading towards EU integration, making it essential to be accepted as a reliable partner in business matters. Ukraine, in contrast, has no record of honoring long–term agreements. As a newly founded state it would have to forgo short–term benefits now in order to build up a reputation for honesty in long–term business relationships what pays off only in the distant future. Given the fragility of its political system, it appears highly unlikely that other players would trust any long–term commitment at face value.

The qualitative analysis of a simple model of the transportation grid shows that investment into links which cannot be covered by contracts is decreased, while investment into alternative but more costly options is increased in order to create countervailing power. We find that depending on the relative strength of these effects and on capacity cost there will be (i) underinvestment, (ii) distorted investment in the sense that more costly options are chosen, (iii) overinvestment, in the sense that total capacity is larger than under full commitment, and (iv) excess capacity which will be left idle at the production stage.

The Eurasian transport system for natural gas offers a unique opportunity to put theoretical results to an empirical test. The various investment options and the associated cost are sufficiently clear to allow for a quantitative specification of the parameters and to confront the results with the historical evidence. The quantitative analysis suggests that strategic reasons do in fact justify the neglect of the old links running through Ukraine and the investment into the new Yamal pipeline, with capacities well above what was needed at that time. In this sense we are able to explain the past investment pattern of the industry.

In its spirit, the analysis of this chapter is obviously related to the large literature on "hold–up" and "second sourcing". Most of this literature assumes that contracts are incomplete due to information problems, which limit external enforcement by a third party. Possible remedies arise from the fact, that an enforcing agency may observe at least some relevant features, which then can be incorporated into the contract as a substitute to improve efficiency. However, investment in transport capacity for natural gas is verifiable, and so are most contract violations during the operating stage. Hence, from the technical side, there appear few reasons to assume that contractual incompleteness and the resulting hold–up problem are of particular relevance in this market. This is confirmed by the fact that, historically, the Eurasian transmission system was developed under long–term agreements. The difficulty arises from the fact that the players involved are sovereign nations or firms strongly connected to their respective governments. In some countries, the separation of business and politics has not been firmly established and there is no truly independent legal system. As there is also no international arbitration system, legal remedies are hardly available even if it is plainly clear who is breaching the contract. Since external enforcement of the agreements is insufficient, commitment can be only credible if players are sufficiently concerned about their reputation.

In this sense the given study is closer to the literature on tax competition among sovereign states (e.g. Janeba [2000]). The focus on multilateral bargaining among heterogeneous players, the explicit modeling of restrictions on contracting in coalition formation, and the quantitative application, however are all novel. While there is a small literature exploring the strategic implication of Shapley bargaining for choice of technology and merger in general models (e.g. Inderst [2003], Jeon [2002]), we are aware of only one previous usage of the Shapley value in applied quantitative studies of industrial organization. Littlechild and Thompson [1977] have applied the Shapley value to analyze how the cost of runway construction are shared among different aircrafts in the Birmingham airport. They found that the existing fee structure resembled theoretical predictions reasonably well.

Finally, our analysis can be related to the literature on the gas industry. Grais and Zheng [1996] and Chollet et al. [2001], and Opitz and von Hirschhausen [2000] provide a quantitative analysis of the strategic interaction in transmission systems for gas. None of them, however, derives the bargaining power endogenously from the architecture of the transmission system. Instead, they assume that Russia has all the bargaining power but is restricted to set simple linear prices, while transit countries determine quantities. Due to double marginalization, the quantities supplied to the markets in Western Europe may be inefficiently low. In this sense, 'excess capacity' is explained by inefficient contracting at the rent–division stage. Hubert and Ikonnikova [2003] analyze multilateral bargaining in the gas industry as a one–stage game, assuming that contracting about investment is efficient. By exogenously restricting investment options, they assess the strategic value of each option, but they cannot explain inefficient investment.

In what follows, we start with the analytical approach to the problem, then present the quantitative results, and conclude.

2.2 The Model

We analyze strategic investment as a two stage game among N players. At the first stage the players negotiate over investments in transport capacities and enter contracts over access to capacities. At the second stage investment costs are sunk, capacities are given and the players bargain about the sharing of the rents from previous investments. Bargaining takes place in the framework of the access rights agreed upon at the first stage. Players are heterogenous in their ability to commit to long-term contracts. Some players are prone to renegotiate access contracts ex post. We assume that the players rationally anticipate the impact of access rights and installed capacities on bargaining at the later stage and solve the game backwards. Hence, we start with the game dividing the rents.

2.2.1 The second stage

At this stage capacities of the network, denote them k, are fixed. The network consists of pipelines $l \in L$, which may have sections located on the territories of the different countries. For a section of a pipeline l which is under control player $i \in N$ we write l^i. To form a complete transport link players cooperate combining their resources. To each coalition $S \subseteq N$ we assigned capacity vector $k(S) = (.., k_l, ..)$, where k_l denotes the capacity of a complete link l. We put $k_l = 0$ if not all players holding a section in l are present in a coalition. Following these notations, the entire network is given by $k(N) = k$.

A coalition S uses its transport capacities $k(S)$ to supply a quantity of gas $q(S) = (.., q_l, ..)$, where q_l is the quantity delivered through the pipeline l. For each pipeline the following must hold $q_l \leq k_l$. The members of a coalition maximize their joint profit $\pi(k(S))$ given the available capacities. The profit of a coalition is a value v assigned to S in the game:

$$v(S) = \pi(k(S)) = \max_{q(S)} p(Q)Q - \sum tc(q(S)), \quad \text{s.t. } q(S) \leq k(S) \qquad (2.1)$$

here $Q = \sum q(S)$ is the total quantity, p denotes the price and tc is the total cost of supply.[2] Determining this way the values for all possible coalitions $\mathbf{S} : S \subseteq N$, we define the value function $v : \mathbf{S} \rightarrow R$ which is also called a "characteristic function".

[2] All expressions for revenues and cost are understood as expected annualized figures over the lifetime of the investment.

A pair $\{v, N\}$ describes a bargaining game of the second stage. To solve this game and to find how the players share joint profits we use the general solution concept of cooperative game theory - Shapley value (1952). The Shapley value, denoted $\phi_i(v)$, assigns a unique payoff to every player $i \in N$. It is based on the assumption that players negotiate efficiently, form the grand coalition, and distribute the total gains based on the expected marginal contribution of players to the various coalitions $S \in \mathbf{S}$. Formally, a marginal contribution of player $i \in N$ to coalition S is defined as $\Delta_i v(S) = v(S \cup i) - v(S \backslash i)$. According to this the Shapley value is given as

$$\phi_i(v) = \sum_{S \subseteq N \backslash i} \alpha_S \Delta_i v(S) \tag{2.2}$$

where $\alpha_S = \frac{|S|! \cdot (|N| - |S| - 1)!}{|N|!}$ is the probability of a coalition S, $|\cdot|$ gives a cardinality of a set. For notational convenience we extend the definition of ϕ to coalitions and write $\phi_S(v) = \sum_{i \in S} \phi_i(v)$.

We choose the Shapley value, as it is the only rule for sharing the profits from multilateral cooperation which fulfills some reasonable criteria: (i) players who do not contribute anything to any of the possible coalitions should receive nothing, (ii) payoffs should only depend on the players role in the game not an assumed differences in personal bargaining power etc. and (iii) we can take expected payoffs under uncertainty (which makes sense if players are risk neutral). Originally, the Shapley solution was obtained from axiomatic reasoning, leaving open the question which particular (non–cooperative) bargaining process would be able to achieve the efficient outcome and the Shapley sharing.[3] Theoretical literature has proposed a number of non–cooperative foundations of the Shapley value.[4] The model of

[3] Myerson (1980) added further appeal to the Shapley value by showing that it is the unique rule for dividing the gains from cooperation which obeys simple rules of fairness and balanced contributions.

[4] Ju [2004] analyzes sequential trade. At each round the players match randomly in pairs. Those who sell their assets leave the game. The value of the assets which a player accumulates equals the value of a coalition of the players whose initial endowments he obtained through trade. When the gains from trade are equally split, the expected profits are given by Shapley value. Inderst [2003] analyze simultaneous negotiations over contingent

Stole and Zwiebel [1996a] and Stole and Zwiebel [1996b], which appears to fit real world bargaining in the gas market particularly well. They look at bilateral negotiations with a central player without whom nothing can be achieved, assuming that all agreements can be renegotiated before any plans are executed. Only the Shapley–sharing of profits is renegotiation–proof. In the Eurasian gas market, Russia is a central player in the sense of Stole and Zwiebel [1996a] and Stole and Zwiebel [1996b] and negotiations with transit countries are usually bilateral. As a rule, there are many rounds of negotiations, resulting in letters of intent, preliminary agreements etc., which will be renegotiated several times before final deals are made.

The common 'random order bargaining' interpretation for the Shapley value is also the most convenient one to illustrate how access rights determine bargaining power. In this case it is considered that players enter the bargaining game sequentially, one by one until the grand coalition N is formed. Every new player entering the bargaining negotiates an agreement with the coalition established by his predecessors and receives his marginal contribution into this coalition as payoff. The marginal value of player's resources will depend on the ordering of players and the resources they have access to. The Shapley value, which is the expected payoff of a player, is the expected marginal contribution assuming that all possible orderings of players are equally likely.

It is worthwhile stressing, that a coalition's payoff does not depend on what the excluded players do. There are no externalities among coalitions at the bargaining stage, because Russia is an essential player. A coalition not including Russia neither receives any income from exporting gas nor does it compete with the group which includes Russia. Later we discuss, that in principle, if an access regime is such, that some other player has an access to production capacities, Russia would no longer be essential. Once competing

contracts. Each member of the higher level in a vertical chain (producer) bargains with every member of the lower level (retailer) simultaneously. Gains from trade are shared equally for every possible contingency, notably, the possibility that other negotiations may fail.

coalitions may form, externalities would arise and we will not be able to represent the rent division sub–game in characteristic function form and to use the Shapley value. But in the present analysis we rule out externalities excluding the possibility to grant access over production capacities.

Once we have the outcome of the second stage determined, we may proceed with the solution for the first stage.

2.2.2 The first stage

At the first stage the players may invest in transport capacities and enter contracts to reallocate control rights over their capacities. By doing so, the players anticipate the effect of their actions on the future payoff vector ϕ. By assumption, some of the players are not able to make long term commitments and are prone to renegotiate their contracts. Therefore, we do not assume efficient bargaining at the first stage, and cannot take it for granted that the grand coalition will form. Only credible players will form coalitions, while unreliable players will stay as single players. The cooperation of players at the first stage is represented by a coalition structure $P = \{M_1, M_2, ..\}$, which is a partition of N, so that $\cup_P M = N$. In general different partitions may form, we denote the set of all possible partitions by $\mathbf{P}$. For members of $M \in P$ we do not assume that they 'unite' or 'merge' in any sense. They will remain independent actors at the second stage. We merely allow that players have an opportunity to cooperate when decide upon access and investments and explicitly analyze which form of cooperation is the best for them. We consider the two dimensions of cooperation in turn.

We start with the access regime. Within a coalition players can modify the access to capacities by granting and/or denying access to their capacities for other members of the coalition. Access rights are changed through contracts. If a player $i \in M$ obtains a right from player $j \in M$ over his resource l^j we write that they enter a contract $A_i^{l^j}$. In our case, each player owns only one section, so we can spare on notations and write A_i^j.[5] We specify what type of contracts the players can enter in the next subsection. For time being, as an example, one can keep in mind a transfer of ownership contract, by which a player i obtains exclusive access to a resource of j. The composition of contracts between members of M is given by A_M. Recall we assume that only each player can enter contracts only with members of his coalition. We denote the set of all feasible contracts for a given coalition M as $A_M \in \mathbf{A}_M$. The access structure for the entire partition is $A_P = (A_{M_1}, A_{M_2}, ..)$.

Access structure affects supply possibilities of coalitions at the second stage, to express this we will write $k(S; A_P)$. Further on, to simplify the notations, we will write $k(S)$ for the capacities available to coalition S under the "natural" access, corresponding to the de facto control over capacities. By definition (2.1) the value of a coalition at the second stage depends on the capacities at its disposal. Hence, a new access structure A_P will give rise to a new characteristic function. To stress this dependency on access structure we slightly abuse the notation and will write $v(S; A_P)$ and $\phi(v; A_P)$. With the physical capacities of the network fixed, access contracts can not increase 'the cake', since $k(N) = k(N; A_P)$ and $v(N) = v(N; A_P)$, but may change the bargaining power of players and the division of cake. Then, a new access regime A_M is beneficial only if it increases $\phi_M : \phi_M(v) < \phi_M(v; A_M)$. This is equivalent to harming the players which are not in the coalition, i.e. $\phi_{N/M}(v; A_M) < \phi_{N/M}(v)$.

Besides access, the value function depends on the installed capacities k. To make this explicit we will write $v_{[k]}$. Together with the access regime, a coalition M will obviously coordinate investments. In principle, a coalition may contemplate investment into a pipeline which has sections under the control of outside players. Although such investment suffers from the 'hold up' problem at the rent-division stage, it may still be sufficiently more efficient to warrant consideration. Since pipeline investment is fairly trans-

[5]The exception is Russia, which owns sections in all the pipelines. But since we will rule out contracts, in which Russia grants access to its resources, there is no ambiguity in this.

parent and straightforward we assume that players can coordinate on the technical implementation of investment even if they cannot cooperate with respect to financing and long term rent sharing. As a result all investment would be in complete links rather than only into single sections. [6] Then, given a coalition structure P every $M \in P$ maximizes its expected profit choosing the optimal access regime and investments given the strategies of outsiders $P \backslash M$:

$$\max_{A_M \in \mathbf{A}_M,\, k_M} \Pi(M, A_P, k) = \phi_M(v_{[k^o + k_M + k_{P\backslash M}]};\ A_P) - I(k_M)$$

where k^o is the original capacities of the network, k_M are capacities installed by M and $k_{P\backslash M}$ are the capacities installed by the outsiders, $I(k_M)$ denotes the corresponding investment cost. Note, the total capacity at the second stage is given by $k = k^o + k_M + k_{P\backslash M}$. For any given coalition structure P, we can solve the problem by looking for the subgame perfect Nash–equilibrium. We will find $\{A_P^*, k_P^*\}$, where k_P^* are the equilibrium capacities of the network under P. In general, there will be many payoff equivalent equilibria because a particular access regime can often be implemented through various contractual arrangements. In these cases, we select the one with the smallest number of elementary contracts. Fortunately, in our case this will be enough to obtain a unique Nash equilibrium for each possible partition $P \in \mathbf{P}$.

In principle, since the profit of a coalition depends on the strategies of other coalitions we have to account for the possible externalities across coalitions.[7]

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[6]With non–cooperative funding but coordinated technical implementation, the total capacity on link l will be given by the sum of the contributions of all players $k_l = \sum_{i \in N} k_{l^i}$ independently to which coalition they belong. Investments along the same track are perfect substitutes. Alternatively, one could assume that the players invests only on their section of a link. In this case investments would be perfect complements and total capacity would be limited by the smallest investment along the track, $k_l = \min_{i \in S} k_{l^i}$. However, this would require, that (out of equilibrium) players spend huge sums over several years on pipeline projects which have no connection on others players' territory and are therefore completely worthless.

[7]For example, by investing into NTG, Russia will decrease the bargaining power of all other players at the second stage. In this sense it imposes a negative externality on other

To do so we represent the game at the first stage in a partition function form by defining the function $V : \mathbf{P} \rightarrow R^{|\mathbf{P}|}$:

$$V(M; P) = \Pi(M; A^*_P; k^*_P) \tag{2.3}$$

Thus, in difference to the second stage game, the values of coalitions M depend on the entire coalition structure. A solution of the game $\{V, N\}$ has to answer two related questions: Which coalition structure P will emerge in equilibrium and how will the players share the resulting payoffs?

Fortunately, we can avoid solving a game in a partition function form. Thanks to the particular structure of investment cost we can collapse the partition function into a simple value function. As we will show in the next section, joining forces is always beneficial. Hence, we predict that all players, who are able to commit, form one large coalition M. The other players remain singletons. In terms of equilibrium partition we obtain $P^* = \{M, \{i\}, \{j\}..\}$, with $\{i, j, ..\} = N \setminus M$. In a sense we replace the grand coalition N of all players with the smaller set M of those who are able to commit. To determine how the members of this coalition share their profit, we follow a solution concept offered by Owen (1977). We define a new game $\{w, M\}$. Its characteristic function, $w : \mathbf{M} \rightarrow R$, where $\mathbf{M} \subseteq \mathbf{S}$ is the set of all possible coalitions which can be formed by the players who can commit, is derived from the original game $\{V, N\}$ as: $w(S) = \Pi(S; A^*_{P_S}; k^*_{P_S})$, where the coalition $S \in \mathbf{M}$ and P_S denotes the partition which is obtained from P by replacing M with S and $M \backslash S$ by singletons.[8] Hence, the payoff of a sub–coalition S of a coalition M reflects S's power in the overall game. The so called Owen value $\psi : M \rightarrow R$ is simply the Shapley value of this modified game. In difference to Owen's original model, the various coalitions $S \in \mathbf{M}$

players. On the other hand, Russia's optimal investment will depend on whether Ukraine and Belarus form a coalition to increase their bargaining power at the recontracting stage, or whether Poland and Belarus form a coalition to invest in Yamal.

[8]In Owen (1977) P_S is given by $\{..S..\}$, i.e. as if the players $M \backslash S$ would 'disappear'. Hart and Kurz (1983) show, that if the payoff of the Grand coalition is constant, both approaches are equivalent and yield the same result as if $P_S = \{..S, M \backslash S..\}$, i.e. the players $M \backslash S$ would 'stay together'. Whether this equivalence, holds true with investment and non–constant payoffs is an open question.

will differ in their investment, hence, result in different payoffs for the Grand coalition in the final game.

2.2.3 Access Regime

Now we specify the feasible access contracts. Following Segal (2003) we distinguish between inclusive and exclusive contracts, and collusion, to characterize cooperation. An inclusive contract I_i^j grants player $i \in M$ access to j's resources without preventing $j \in M$ from using them on his own. By changing the access regime a contract give rise to a new value function: $v(S; I_i^j) = v(S \cup j)$ if $i \in S$; and $v(S)$ otherwise. Thus, at the second stage the inclusive contract makes a difference for subsets S including i but not including j. The effect of the inclusive contract on the expected share of a third player $k \notin M$ is given by $\sum_{S:i \in S, j \notin S} \alpha_S \Delta^2_{kj} v(S)$, where

$$\Delta^2_{kj} v(S) = v(S \cup k \cup j) + v(S \backslash k \backslash j) - v(S \backslash k \cup j) - v(S \backslash j \cup k) = \Delta^2_{jk} v(S)$$

denotes the impact of j's inclusion on the marginal contribution of k. A sufficient condition for an inclusive contract to impose a negative externality on a third player k is that the included player j is substitutable to k in the presence of i, i.e. $\Delta^2_{kj} v(S \cup i) \leq 0,\ \forall S$. Note, that the contract I_i^j weakens player j's bargaining power, because his marginal contributions to all subsets $S : i \in S, j \notin S$ are reduced to zero. Hence such a contract is only feasible, if (i) player j can commit to grant i access to his resources, and (ii) player i can either compensate j for his loss in bargaining power up–front or commit to compensate later.

An exclusive contract E_i^j gives player i the right to exclude player j. It amounts to: $v(S; E_i^j) = v(S)$ if $i \in S$; and $v(S \backslash j)$ otherwise. The exclusive contract makes a difference only for subsets S which include j but not include i. A sufficient condition is, that for a third player k to suffer from the exclusion of j, is that he is complementary to j in the absence of i, i.e. if

$\Delta^2_{kj} v(S \backslash i) \geq 0, \quad \forall S$. Note, that the contract weakens player j's bargaining power, because his marginal contributions to all subsets $S : i \notin S, j \in S$ are reduced to zero. Hence such a contract is only feasible, if (i) player j can commit to grant i veto over the use of his resources, and (ii) player i can either compensate j for his loss in bargaining power up–front or commit to compensate later.

As is discussed in more detail in Segal (2003) full collusion in which one player, say i acts as a proxy player for the others, which become dummies can be implemented by a combination of the two contracts. The inclusive contract gives the proxy player access to the resources of the other players. The exclusive contract prevents the rest from using these resources on their own, hence, $v(S; C_i^j) = v(S \cup j)$ if $i \in S$; $v(S \backslash j)$ otherwise. A sufficient condition for the union C_i^j to be detrimental for a third player k is $\Delta^3_{ijk} v(S) \leq 0$. In this case k decreases the complementarity between the colluding players i and j. Note, that $\Delta^3_{ijk} v(S)$ is independent of the ordering of players. As the Shapley value is symmetric it does not matter which player is made the proxy and which the dummy. Hence, the contract requires (i) that j (or i) is able to commit to fully hand over control over his resources and (ii) that i (j) can commit to compensate j (i) for his complete loss of bargaining power, or to pay up–front. We summarize these results in proposition 1:

Proposition 1 *With capacities fixed, $i, j \in M$:*

1. *Contracts $A_i^j, A \in \{I, E, C\}$ are only feasible if i can compensate j up–front or commit to make payments in the future, moreover we have:*
2. *I_i^j is beneficial and feasible if:*
   $\Delta_{I_i^j}(k) = \sum_{S: i \in S, j \notin S} \alpha_S \Delta^2_{kj} v(S) < 0,\ \forall k \notin M$, *and j can commit to grant i access.*
3. *E_i^j is beneficial and feasible if:*
   $\Delta_{E_i^j}(k) = \sum_{S: i \notin S, j \in S} \alpha_S \Delta^2_{kj} v(S) > 0,\ \forall k \notin M$, *and j can commit to grant i veto.*

4. C_i^j *is beneficial and feasible if:*
$\Delta_{C_i^j}(k) = \sum_{S:i\in S, j\notin S} \alpha_S \Delta^2_{ijk} v(S) < 0,\ \forall k \notin M$*, and* j *can commit to give* i *control.*

Where $\Delta_{I_i^j}(k) = \phi_k(v; I_i^j) - \phi_k(v)$. It is straightforward to extend the proposition to multilateral contracts.

To prevent externalities at the second stage we rule out contracts which give other players access to pipelines and production in Russia. In other words, we focus on access rights over pipelines only, but not to production.It is worth recalling, that none of the transit countries, considered in this chapter, made a serious move to establish itself as an independent supplier of natural gas for Europe. Hence, the assumption is in line with the developments observed. It is also natural to assume that a player can not have a right to exclude all others from a resource without having access to it himself. Thus, we use exclusive contracts only to emphasize the distinction between access and ownership, not as a standing alone arrangement. Formally the contract space is restricted to $\mathbf{A}_M = \{A_i^j : A \in \{I, C\}; i, j \in M, j \neq R\}$. The restriction on exclusion also maintains a distinction between section of links, for which there exists always a single player who has access, and complete links, which may require more than one player to operate.

2.3 Qualitative Analysis

In this section we use the theoretical framework to provide for a qualitative analysis of strategic investment in the Eurasian gas system. We consider four independent players Russia, Poland, Belarus, and Ukraine denoted R,P,B, and U, respectively. The situation we have in mind is the state of the system in the early nineties, that is before Yamal had been built. As to the ability of the players to commit, we look at two different cases. In the first we assume that only Ukraine lacks this ability. This captures reasonable expectations in the early nineties, when Russia and Belarus apparently found a long–

term solution for the transit problem. However, these agreements unraveled later on and in the second variant we assume that Belarus, as Ukraine, can neither make long–term commitments nor pay up–front. Investment possibilities exist along three tracks: North European Gas Pipeline, Yamal, and Ukrainian system, denoted (n, y, u). As should be clear from the description in section 1.1, the smallest coalition for y is $\{R, P, B\}$, u requires at least $\{R, U\}$, and n needs only $\{R\}$.

We have already described the features of the various investment options in detail in the section 1.2. Here, we assume that marginal investment cost for new capacities are piecewise constant. The existing capacities in Ukraine, denoted u_o are available at zero investment cost. Upgrade of the Ukrainian system will give the total capacity of $\bar{u}$ and has the lowest marginal investment cost I_u. The construction of new pipelines along the Yamal–track through Poland is more expensive, but still cheaper than going offshore (NEGP), i.e: $I_u < I_y < I_n$. Further, we assume that marginal operating cost are the same for all tracks. Hence, capacities on the different tracks are perfect substitutes, at the production stage.[9] This allows us to lump all capacities together and evaluate the marginal impact of capacity on operating profits as: $\max[\pi'(n + y + u + u_o), 0]$, where π is defined in (2.1). Note that π' cannot be negative, as it is always possible to leave capacity idle at the production stage.

To answer the question, which agreements the various possible coalitions would choose at the contracting stage, we have to compare gains of players under all possible contracts at the supply stage. In principle, the gains from entering different possible coalitions may depend on the capacities. However, it turns out that by assuming that Ukraine is prone to recontracting and cannot pay up–front, we can effectively rule out all contracts except I_R^{PB} by applying proposition 1. We formulate this finding in the following proposition:

[9]This assumptions will be dropped in the numerical part. At the rent–division stage only operating cost matter, and with respect to these Yamal is actually slightly cheaper than the southern track.

Proposition 2 *For $P_{\{RPB\}} = \{\{R,P,B\},\{U\}\}$ the access regime is equivalent to $v(\cdot; I_R^{PB})$. For all other partitions the access regime is natural with $v(\cdot)$ and the same as for $P_\emptyset = \{\{R\},\{P\},\{B\},\{U\}\}$.*

Proof: It is easy to see that contracts involving Ukraine are not feasible. Ukraine cannot afford contracts of the format A_U^i and cannot make the commitments required by A_i^U. Thus, it is sufficient to consider coalition structures in which U is a singleton, i.e. $P = \{..,\{U\}\}$. Furthermore, P and B are symmetric in this game. Hence, we should check only $P_\emptyset = \{\{R\},\{P\},\{B\},\{U\}\}$, $P_{RP} = \{\{R,P\},\{B\},\{U\}\}$, $P_{RPB} = \{\{R,P,B\},\{U\}\}$, and $P_{BP} = \{\{R\}, \{B,P\},\{U\}\}$. We start by analyzing the impact of contracts, which coalitions can sign, and then we turn to coalition structures.

Consider the contract I_R^B. By proposition 1(2) it is feasible, provided that R and B belong to the same coalition at the investment stage. This contract will weaken U at the recontracting stage, because for all coalitions including R and P, the included player B is substitutable to the outside player U. As a result I_R^B decreases U's marginal contribution in all orderings for which both, R and P, precede U and U precedes B. These are 2 out of possible 4!=24 orderings, both assessing the marginal contribution of U to $\{R,P\}$. To avoid cumbersome notations in formulas we will omit brackets indicating coalitions and write $RPUB$ instead of $\{R,P,U,B\}$. Hence, the impact of I_R^B on Ukraine is given as:

$$\begin{aligned}\Delta_{I_R^B}(U) &= \frac{1}{12}\Delta^2_{UB}v(RP)\\ &= \frac{1}{12}\left[(v(RPUB)-v(RPB))-(v(RPU)-v(RP))\right] < 0\end{aligned}$$

The same contract will strengthen P's bargaining power because P is complementary to B in the presence of R. The relevant orderings are those for which R precedes P which is followed by B. Hence:

$$\begin{aligned}\Delta_{I_R^B}(P) &= \frac{1}{12}\Delta^2_{PB}v(R) + \frac{1}{12}\Delta^2_{PB}v(RU)\\ &= \frac{1}{12}\left[(v(RUPB)-v(RU))+(v(RPB)-v(R))\right] > 0\end{aligned}$$

The last expression is obtained using the fact that at the recontracting stage the inclusion of only either B or P to a coalition does not change its value under the natural access, i.e. $v(RP) = v(R)$, $v(RUP) = v(RU)$.

Now we can show that forming a coalition $\{R, B\}$ in partition P_{RB} the players have nothing to gain from changing the access regime. Moreover, the contract I_R^B is harmful for Russia and Belarus, because the total impact on all outside players is positive:

$$\begin{aligned}\Delta_{I_R^B}(U) + \Delta_{I_R^B}(P) &= \frac{1}{12}\Delta^2_{UB}v(RP) + \frac{1}{12}\Delta^2_{PB}v(R) + \frac{1}{12}\Delta^2_{PB}v(RU) \\ &= \frac{1}{6}\Delta_B v(RPU) > 0\end{aligned}$$

where the last line is obtained, by rewriting all expressions in terms of marginal contributions of B (recall that $\Delta^2_{UB} = \Delta^2_{BU}$) and simplifying the result.

If the contract is signed under the partition P_{RPB} it is beneficial, as it weakens the only outsider - Ukraine. However, we can prove, that the members of $\{R, P, B\}$ can improve their position even further by multilateral inclusion $I_R^{PB} = I_R^P(I_R^B)$. As well as I_R^B the contract I_R^P decreases U's marginal contribution, but with respect to the coalition $\{R, B\}$. Using the same reasoning as above we calculate the impact of I_R^{BP} on Ukraine as:

$$\begin{aligned}\Delta_{I_R^{PB}}(U) &= \frac{1}{12}\Delta^3_{UBP}v(R) \\ &= \frac{1}{12}\left[(v(RPBU) - v(RPB)) - (v(RU) - v(R))\right] < 0\end{aligned}$$

Since the contribution of Ukraine into coalition $\{R\}$ is not less than to $\{R, P\}$ the impact of I_R^{PB} is not smaller than of I_R^B. This proves the first claim of the proposition 2. Furthermore, one may notice, that the members of $\{R, B\}$ or $\{R, P, B\}$ will not sign exclusive contract, as this would benefit U according to proposition 1(3).

Similar to P_{RB} in partition P_{PB} Poland and Belarus can not improve upon the original access regime v. The inclusive contract will strengthen the bargaining position of Russia more, than weaken the position of Ukraine.

Table 2.1: Access Regime and Rent Sharing in Terms of Value Function

$\phi_R(v)$	:	$+\frac{5}{12}v(R) + \frac{1}{12}v(RPB) + \frac{1}{4}v(RU) + \frac{1}{4}v(RPUB)$
$\phi_P(v)$	:	$-\frac{1}{12}v(R) + \frac{1}{12}v(RPB) - \frac{1}{4}v(RU) + \frac{1}{4}v(RPUB)$
$\phi_B(v)$	:	$-\frac{1}{12}v(R) + \frac{1}{12}v(RPB) - \frac{1}{4}v(RU) + \frac{1}{4}v(RPUB)$
$\phi_U(v)$	:	$-\frac{1}{4}v(R) - \frac{1}{4}v(RPB) + \frac{1}{4}v(RU) + \frac{1}{4}v(RPUB)$
$\phi_{RPB}(v; I_R^{PB})$	:	$+\frac{1}{2}v(RPB) + \frac{1}{2}v(RPUB)$
$\phi_U(v; I_R^{PB})$	:	$-\frac{1}{2}v(RPB) + \frac{1}{2}v(RPUB)$
ϕ_{RPBU}	:	$v(RPBU)$

Hence, all coalition structures with bilateral coalitions have the same access structure as $P_\emptyset$. ∎

Note that proposition 2 does not depend on the capacities. In our special context we can first determine the optimal access regime and then analyze the incentives for investment. Furthermore, it gives a lot of mileage for proving that at the investment stage the coalition involving Russia is not effected by externalities from other coalitions, which is a pre-condition for defining a value function for the investment game. If there are any externalities these have to work through investment, not through the access regime.

Table 1 describes the effect of changing the access regime for given capacities. It gives the Shapley values at the rent sharing stage for the various players for different coalition structures and the corresponding access regimes.[10] The first four rows refer to $P_\emptyset$, the case in which the four players act independently and the access regime is given by v. The next two rows refer to P_{RPB} with Russia, Poland and Belarus forming a coalition in which Poland and Belarus commit to grant Russia access to their transport pipelines $v(\cdot; I_R^{PB})$.

Using the definition of the value function (2.1) we can obtain the shares of rent in terms of operating profits and capacities from table 1 by substituting

[10]Note that $v(P) = v(B) = v(U) = v(PU) = v(BU) = v(PB) = v(PUB) = 0$, as these coalition cannot establish a complete link.

$\pi(n+y+u+u_o)$ for $v(RPBU)$, $\pi(n+y)$ for $v(RPB)$ etc. For a benchmark case, assume that all players could commit not to recontract, form the Grand coalition at the investment stage and invest to maximize industry profits, without any strategic considerations. They would solve:

$$\max_{n,y,s} \Pi_{RPBU} = \pi(n+y+u+u_o) - I_n n - I_y y - I_u u; \quad s.t.\ u \leq \bar{u} - u_o \tag{2.4}$$

For further reference denote the solution (n^*, y^*, u^*).

In order to streamline exposition we assume that in the initial situation, with installed capacity u_o, some investment into upgrading the Ukrainian system (the cheapest option) is warranted $I_u < \pi'(u_o)$. Yamal is the second best option and will always dominate investment on n, hence, we may have two possible outcomes: $(n^* = 0, y^* = 0, u^* \leq \bar{u} - u_o)$ or $(n^* = 0, y^* > 0, u^* = \bar{u} - u_o)$. First order condition for an interior solution are $\pi'(u^* + u_o) = I_u$ and $\pi'(\bar{u} + y^*) = I_y$, respectively.

Now we consider the coalition structure $P_{\{RPB\}}$. Russia, Poland and Belarus maximize

$$\Pi_{RPB} = \frac{1}{2}\pi(n+y+u+u_o) + \frac{1}{2}\pi(n+y) - I_n n_{RPB} - I_y y_{RPB} - I_u u_{RPB}$$

and Ukraine maximizes

$$\Pi_U = \frac{1}{2}\pi(n+y+u+u_o) - \frac{1}{2}\pi(n+y) - I_n n_U - I_y y_U - I_u u_U$$

where k_i, $k \in \{n, y, u\}$ and $M \in \{RPB, U\}$ denotes M's investment into the capacity k and $k = \sum k_M$ is the total capacity. The expressions are obtained from the expected rent given in the fifth and sixth row of table (1). Since $\pi'(n+y+u+u_o) < \pi'(n+y)$, Ukraine would never invest on y or n. However, provided that $\pi'(u_o)/2 < I_u$ it would not even invest into the upgrade of the southern system, and the same holds true for the coalition. Investment is discouraged, because both sides anticipate, that returns have to be shared with the other side at the recontracting stage, the classic hold–up problem. The incentives to invest in y, however, are much increased. For the coalition the marginal returns are given by $\pi'(y_{RPB})/2+\max[\pi'(y_{RPB}+u_o),0]/2$. Not only that marginal returns on investment on Yamal receive full weight, the competing capacities in the south are strongly discounted in the evaluation. This increases the incentives to invest well above what would prevail in the first best situation. Depending on the relative strength of these effects and on capacity cost there will be (i) underinvestment, (ii) distorted investment in the sense that more costly options are chosen, (iii) overinvestment, in the sense that total capacity is larger than under full commitment, and even (iv) excess capacity which will be left idle at the production stage.

Proposition 3 *If I_y and I_u are high enough, there will be underinvestment. If I_y and I_u are low enough, there will be overcapacity and even unused excess capacity.*

Proof: Note that y_{RPB} is continuous in I_y. Hence it is sufficient to prove underinvestment for large enough I_y and excess capacity for low enough I_y. We obtain underinvestment: if $I_y > \pi'(u_o)/2 + \pi'(0)/2$ then $y_{RPB} = y^* = 0$, if at the same time $I_u > \pi'(\bar{u})/2$ then $0 = u_{RPB} < u^*$. For excess capacity we have to show that $\exists I_y$ so that $\pi'(u_o + y_{RPB}) < 0$. Assume $I_y \rightarrow I_u$ and define $\hat{y}(I_u)$ by $2I_u = \pi'(\hat{y})$. Obviously $\hat{y} \leq y_{RPB}$, hence $\pi'(\hat{y}) > \pi'(u_o+\hat{y}) \geq \pi'(u_o+y_{RPB})$. Evaluated at $I_u = 0$ we obtain $0 = \pi'(\hat{y}(0)) > \pi'(s_o+\hat{y}(0)) > \pi'(u_o + y_{RPB})$.[11]

Now we turn to the second case and assume that Belarus, like Ukraine, is prone to recontract. This corresponds to the only possible coalition structure $P = \{\{R,P\},\{B\},\{U\}\}$. Anticipating bargaining over rents with Belarus, Russia and Poland would no longer benefit from a contract granting access

[11] The intuition behind proposition 3 is similar to that provided by Janeba [2000] for countries competing to attract investment, which can then be exploited through taxation. He derives that depending on the cost of capacity there may be underinvestment due to the hold–up problem or costly duplication and excess capacity to stimulate competition between the countries at the tax setting stage. However in Janeba [2000] there is no bargaining over the rents.

to capacities at Yamal (proposition 2). Hence, their expected rents are given by $\phi_R(v) + \phi_P(v)$ and investment is chosen to maximize:

$$\begin{aligned}\Pi_{RP} =& \frac{1}{3}\pi(n) + \frac{1}{6}\pi(n+y) + \frac{1}{2}\pi(n+y+u+u_o) \\ & - I_n n_{RP} - I_y y_{RP} - I_u u_{RP}\end{aligned}$$

Belarus maximizes

$$\begin{aligned}\Pi_B =& -\frac{1}{12}\pi(n) + \frac{1}{12}\pi(n+y) - \frac{1}{4}\pi(n+u+u_o) + \frac{1}{4}\pi(n+y+u+u_o) \\ & - I_n n_B - I_y y_B - I_u u_B\end{aligned}$$

Obviously, Belarus would neither invest in u nor in n. Its incentives to invest into y are ambivalent. On the one hand the coefficients of the terms which take y into account (1/12 and 1/4) sum up to only less than half. In this sense returns to investment are sharply discounted. On the other hand, some weight (1/12) is put on a situation in which marginal returns are evaluated well above social returns because the capacities u are ignored. The coalition's incentives to invest in Yamal are somewhat stronger (with coefficients 1/6 and 1/2) but still weaker than in the previous case. Incentive to invest in NEGP, in contrast, are unambiguously enhanced. Not only that full weight is given to its marginal impact on operating profits. Marginal revenues are also evaluated giving little weight to the capacities y and u. This implies that equilibrium investment may be distorted even further towards high–cost off–shore links if Belarus's ability to enter long–term agreements is in doubt.

2.4 Quantitative results

Based on the assumptions from the section 1.2 we solve numerically for the equilibria of the various coalition structures. It turns out that in equilibrium there would be no investment in links without assured access. In other words, investment in Yamal requires the coalition of all three participants (P_{RPB}). If this coalition fails to form (P_{RP}, P_{RP} ..), there will be only investment in North-Trans-Gas.[12] Investment into unsecured links occurs only out of equilibrium. For example, if R did not invest in NEGP, P and B would to invest small amounts into Yamal even if there were not in a coalition with Russia and access would not be assured (P_{BP}, $P_{\emptyset}$). Similarly, Ukraine would invest into upgrading the old system on its own, if there were no investment on Yamal or NEGP. However, given the strong strategic incentive to invest in Yamal, respectively NEGP, these constellations do not constitute equilibria. Table 2.2 gives the results in terms of aggregate figures and table 2.3 in terms of the shares of the various players.

As in the previous section we start with the reference case, in which all players could commit and optimize investment to maximize industry profits (coalition structure P_{RPBU}). In this case investment would have been: $\{n^*, y^*, u^*\} = \{0, 0, 15\}$, i.e. investment is concentrated on the upgrading of the old system in Ukraine from 70 bcm/a to 85 bcm/a. This capacity would have been fully used, yielding an annual operating profit (rent) of \$ 5.789 bn and a net profit of \$ 5.673 bn. However, this outcome is not feasible given our assumption about Ukraine.

For the coalition of Russia, Poland and Belarus (P_{RPB}) we obtain a different picture. Rather than using the cheapest option in the Ukraine, new investment is strategically directed into a large Yamal project with 60 bcm/a capacity. Together with the already existing 70 bcm/a of Ukold, total capacity reaches 130 bcm/a of which a staggering 40 bcm/a are subsequently left idle. Sales of 90 bcm/a generate an operating profit of \$ 5.826 bn, which is reduced by high investment cost to a net profit of only \$ 4.530 bn. In order to calculate how Russia, Belarus and Poland share the joint profit we have to look at the game in which every player acts on its own ($P_{\emptyset}$). In equilibrium there is no investment in Yamal but a very large investment of 54 bcm/a in North European Gas Pipeline resulting in a total capacity of

[12]This implies that equilibrium investment does not depend on the formation of bilateral coalitions. Hence, in equilibrium there are no externalities across coalitions through investment. Together with proposition 2 we can rule out externalities altogether and calculate the Owen value for the game at the investment stage.

Table 2.2: Equilibrium Capacities, Quantities, Aggregate Profits

	invest $\{n, y, u\}$ bcm/a	capacity [quantity] bcm/a	price \$/tcm	operat profit/rent \$ mln/a	invest cost \$ mln/a	net profit \$ mln/a
First best	$\{0, 0, 15\}$	85 [85]	119	5789	116	5673
Coalition: RPB	$\{0, 60, 0\}$	130 [90]	118	5826	1296	4530
No Cooperation	$\{54, 0, 0\}$	124 [88]	118	5755	1345	4410

124 bcm/a at the production stage.

The figures for profit sharing explain why countervailing power is so important in this transmission system. If Russia had naively followed the first best investment strategy, paying for the upgrade in Ukraine up–front and then had been forced to bargain over rents, its bargaining power would have been poor. Rents would have been shared equally between Russia and Ukraine because both players are necessary for the operating of the system. The resulting net–profit of \$ 2.779 bn for Russia compares to \$ 4.073 bn which Russia can achieve by forming a coalition with Poland and Belarus and spending \$ 1.296 bn annualized investment cost on Yamal. Russia increases its net–profit, mainly by decreasing Ukraine's share. While total profit declines by app. \$ 1.143 bn due to inefficient investment, Russia increases its profits by roughly the same amount. With a \$ 0.106 bn each, the shares of Poland and Belarus are modest, because Russia's outside option, North–Trans–Gas, ensures already a hefty net–profit of \$ 3.967 bn.

As to the magnitude, these figures appear to overestimate the distortion if compared to real world investment. While investment in Upgrade was in fact close to zero, the Yamal pipelines has only half of the capacity we predict. This discrepancy between the predictions of the model and reality is not to be resolved by reasonable changes in the numerical values of our parameters. Instead, we see two structural deficiencies of our model which are responsible. First, our model tends to exaggerate the strategic aspect by assuming that investment can take place only once. In reality bargaining

Table 2.3: Shares of Net–Profits and Rents

variant	Russia		Poland	Belarus	Ukraine
	(rent)	profit	profit	profit	rent
	$ mln/a	$ mln/a	$ mln/a	$ mln/a	$ mln/a
Grand Coalition		4847	27	27	773
First best investment but recontracting	(2895)	2779	0	0	2895
Coalition: RPB		4073	106	106	245
No Cooperation	(5312)	3967	0	0	443

over rents is not only influenced by capacities established in the past but also by options to extend the system in the future (Hubert and Ikonnikova [2003]). This will reduce the need to actually spend money on capacities. It is worthwhile to recall that plans, feasibility studies and even some preparatory investment have been made for a capacity of to 56 bcm/a along the Yamal track. Then pipelines with a capacity of 28 have been installed, but investment in compressors stopped short at 18 bcm/a. Given that pipelines are already in place, an increase of capacity by adding compressors is cheap and fast and everyone understands this possibility, hence there is no need to actually waste the money.

Second, our assumption, that players can be clearly separated into those who can commit and those who cannot is overly simplistic. The assumption that Poland and Belarus can commit, appears not unreasonable for the early nineties, but it is cast into doubts by recent developments. Attaching a small probability of recontracting with either Poland or Belarus would certainly reduce the appeal of the Yamal project. However, a quantitative assessment of this argument is left for further research.

2.5 Conclusions

In this chapter we derive the bargaining power of the different players along the supply chain of Eurasian gas endogenously from the architecture of the transmission system and its possible extensions by applying cooperative game theory for multilateral negotiations. As the number of players is small and the cost parameters of gas transport are well–known, we assume that the members of the Eurasian supply chain bargain efficiently and make the best use of the existing transmission network. This allows us to use the Shapley value to calculate the sharing of profits along the vertical supply chain.

However, in the case of pipelines much of the investment in transport infrastructure is sunk, and therefore prone to ex–post exploitation of quasi–rents. Since there is no international court system to enforce contracts between independent nations, long–term commitments can only be achieved between players who are sufficiently concerned about their reputation. If opportunistic renegotiation cannot be prevented, the well–known hold-up problem may lead to inefficient investment, even if the bargaining process itself is efficient. While we assume that contracts are complete regarding prices and quantities, as is required for the efficient use of the existing network, we allow them to be incomplete with respect to the lifetime of investment projects. This means that at least some players may recontract in order to appropriate quasi rents from sunk investment. Since other players will anticipate recontracting, they may refuse to invest, or overinvest in alternative routes in order to create countervailing power.

Our qualitative and quantitative analysis show that in spite of large capacity cost, overinvestment and excess capacity are not a mere theoretical possibility in the Eurasian transport system for natural gas. Given the particular geography of this network, and the inability to make credible long term commitments or large up–front payments on part of Ukraine, there is in fact much to gain from creating countervailing power. Hence, overinvestment into new pipelines and underinvestment into existing ones are a result of rational strategic calculations.

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Chapter 3

Bargaining with externalities and strategic value of investment options

3.1 Introduction

In this chapter we proceed with the analysis of the current situation in the Eurasian gas supply network. To reflect the important role, which gas from the Caspian region will play in the future, we extend the list of players by Turkmenistan, Azerbaijan, and Iran. As already discussed in chapter 1, if these countries succeed in cooperation, a competing supply chain will form. This will impose negative externalities on the Russian supply coalition and change the power structure in the network. In this chapter we address two interrelated questions: whether the competing supply chains are likely to form and how the players bargain in the presence of externalities.

During the recent negotiations concerning compensation for gas transit, Ukraine and Belarus exploited their control of the essential transport capacities to achieve higher profit. However, Russia can build additional capacities and by this change the *status quo* balance of power. Therefore, the view that the bargaining power is determined solely by existing capacities, is somewhat *shortsighted*. A *farsighted* player should take into account both the existing capacities and all options to extend the network to obtain a comprehensive assessment of the bargaining power. For different pipelines it takes different time to be built. Intuitively, the faster a pipeline can be built, the greater will be its impact on the power structure in the network and hence, on payoffs. In this chapter, we look at how the balance of bargaining power changes depending on the availability of investment options. We adopt a shortsighted and farsighted perspectives and thus, avoid the complexity of a dynamic model, in which the options are to be discounted to reflect the time required to build a pipeline. Instead, we provide a range of possible outcomes of a dynamic model. We assess the strategic relevance of different pipeline options to understand the recent developments in the Eurasian gas supply network, namely concessions of Russia to Turkmenistan, the tougher attitude of Russia vis-a-vis Ukraine and Belarus, and the initiation of expensive pipeline projects, such as TCP, Nabucco, and NEGP.

We develop a framework to analyze the cooperation between producers and transiters and examine the balance of power in the Eurasian gas supply network. As in the previous chapter, we derive the bargaining power and a coalition structure in the network endogenously. However, in the presence of externalities, we cannot describe the bargaining game in characteristic function form, since a value of a coalition depends on the allocation of the players outside. We also can not apply solution concepts, such as Shapley value (1953), Owen value (1977), core, and etc.. Instead we introduce a model of bargaining and endogenous coalition formation game in a partition function form. The partition function assigns a profit to each coalition depending on the partition of players into coalitions and hence, allows to capture externalities.

A number of solution concepts have been proposed for games in partition function form (PFF). Some authors have developed extensive form approaches to a PFF game, e.g. Bloch [1996], Ray and Vohra [1996], Ray and Vohra [1999], and Gomes [2005]. These models are differ in protocols, which determine the order of players' moves and hence, how a game develops. To avoid protocol dependency of the outcome various axiomatic solutions have proposed, e.g Do and Norde [2002], Ju [2004], de Fontenay and Gans [2004], and Clippel and Serrano [2005]. The models characterize a modification of the Shapley value and are based on the assumption that a grand coalition always forms. This assumption considerably limits the implication these solutions. For our analysis, we choose another solution concept which has been proposed by Maskin (2003). The approach of Maskin (2003) is based on the "random order bargaining" concept, which essentially describes a game in extensive form. However, to specify the development of the game Maskin (2003) uses a set of axioms. Thus, Maskin (2003) offers a procedure similar to the one used for the Shapley value. A major advantage of Maskin's (2003) axiomatic solution is that it determines both the expected coalition structure and the expected payoffs of players endogenously.

Through our quantitative analysis we derive the strategic importance of different investment options. In this chapter we do not explain investment patterns as such, but rather investigate how the mere possibility to extend the network affects the balance of bargaining power. In particular, we quantify the effect of every particular pipeline option on the bargaining position of players. Our results highlight the importance of outside options in strengthening the bargaining power. We find that the expensive North European Gas Pipeline as well as TCP and Nabucco and valuable for strategic reasons. We show how the bargaining power of the transiters vis-a-vis the producers depends on bypass options and how fast they can be built. The possibility to increase capacities of the transiters do not yield any strategic benefit to the producers, but can only weaken their bargaining position. This fact unfolds why Russia postpones investing to upgrade and renovate the Ukrainian transmission system and the Yamal pipeline in Belarus.

Apart from other differences, previous studies of the Eurasian gas supply network, e.g. Grais & Zheng (1996), von Hirschhausen et al. [2005], and Holz and Kalashnikov [2005], focus only on the relation of Russia and its transiters, so that the issue of externalities does not arise. Overall, we are not aware of any study tackling the coalition formation issue. Hence, we pioneer in this respect as well.

From a standpoint of a general bargaining problem with externalities, our work relates to studies on other topics. In particular, Eyckmans and Tulkens [2001] explore the issue of Kyoto protocol, where players are countries and externalities are emissions affecting the environment of others. Jehiel and Moldovanu [1996] study a patent acquisition problem, in which oligopoly firms collude to buy an innovation from a rival. Fridolfsson and Stennek [2002] analyze preemptive mergers, where firms merge with the hope of avoiding the negative externalities of being an "outsider" of the deal. Finally, Calvert and Dietz [1998] consider the formation of political parties. All these studies use the Nash equilibrium and Markov equilibrium solution concepts to find an outcome of a coalition formation game. To the best of our knowledge, our work is the first attempt to use the solution of Maskin (2003). Besides, we are aware of only two previous application of a partition function form game to analyze a real world problem. Eyckmans, Tulkens (2001) applied PFF game to study greenhouse gas emissions and Pintassilgo (2003) use PFF game to analyze the Northern Atlantic bluefin tuna fisheries. Both focus on a fair sharing rule for the distribution of the returns from cooperation, which will ensure stability of a coalition structure. Our approach is different since we derive the sharing of the profit endogenously.

The rest of the chapter is organized as follows. In the following section we proceed with the model and its solution. Next, we present the results and their interpretation. Section 4 concludes.

3.2 The model

3.2.1 Preliminaries

In this section we introduce a formal model of the game and its solution. Let $N = \{.., i, ..\}$ be a set of players. The players form coalitions $S_k \subseteq N$. The set of coalitions $P = \{.., S_k, ..\}$ is called a *partition*, or a coalition structure. We denote a set of all possible partitions by $\mathbf{P}$. We assume coalitions embedded in any partition are pairwise disjoined $S_k \cap S_h = \emptyset$ for all $k \neq h$. Further, we will distinguish terminal partitions formed by all the players $P^N : \bigcup_{k=1}^{|P^N|} S_k = N$, where $|\cdot|$ denotes cardinality, and partial partitions P formed by $K \subseteq N$. With respect to a terminal partition, we say that a grand coalition forms when all the players cooperate forming one coalition $P^N = \{N\}$.

We model the situation in which multiple competing coalitions may form. The profit, or value, of a coalition may not only depend on the members of the coalition, but also on the allocation of the outsiders into coalitions, i.e. on the entire partition. Therefore, we choose the partition function approach proposed by Thrall and Lucas (1963). A partition function $w:\ P^N \rightarrow R^{|P^N|}$ maps all possible terminal coalition structures $P^N \in \mathbf{P}^N$ into a vector of values for embedded coalitions $w(S; P^N)$.

The pair (N, w) represents a game in a partition function form (PFF). The advantage of the PFF approach is that it captures the presence of externalities. Formally, we speak of externalities whenever

$$\exists S:\quad w(S;P) \neq w(S;P^{'})\ ,\quad \text{for}\quad P \setminus S_k \setminus S_j = P^{'} \setminus \{S_k \cup S_j\} \tag{3.1}$$

i.e. there is at least one coalition, which value changes with a change in a partition. When the inequality sign in (3.1) becomes "greater than", the externalities are negative. In this case the union of the coalitions S_k and S_j impose a loss on S. If the inequality sign is "less than", the externalities are positive. This means that the merger of S_k and S_j brings S a gain.

The presence of externalities prevents us from using the standard approach of cooperative game theory - the characteristic function (CF), for which a number of general solution concepts exists such as core, Shapley value, and bargaining set. The characteristic function assigns a coalition its worth disregarding the actions of outsiders. Hence, it cannot account for external effects across coalitions. For that reason, we use the partition function approach instead.

Similar to Shapley (1953), we want the solution of the game (N, w) to assign a vector of expected payoffs $\mathrm{E}[\psi^*]$ to all players $i \in N$. However, unlike a game in a characteristic form, we can not expect that the grand coalition will always form. Therefore, we are also interested in finding a probability distribution of equilibrium partitions $p(P^*)$.

3.2.2 Solution concepts for PFF

To solve a PFF game various algorithms have been proposed. Different works focus on different outcomes for PFF games. Some authors assume that the grand coalition always forms in equilibrium and offer an axiomatic approach to derive a vector of payoffs to players as a modified Shapley value, e.g. Do, Norde (2002) and Ju (2004). Others search for equilibrium, or stable, coalition structures assuming a particular exogenous payoff function, see Bloch and Gomes [2006], Bloch [2002], Bloch [1996]. A series of works developed a core concept for PFF considering a simultaneous-move game with various sharing of coalitional profits (see Funaki and Yamato [1999], and Tulkens and Chander [1997], and Koczy [2004]). To find the values of coalitions, such works assume that players have "conjectures" on outsiders' actions. Conjectures can be pessimistic, when outsiders act as to minimize the value of a coalition, or they can be optimistic, when the structure of outsides is such that a coalition achieves its maximum value, or they can be a probabilistic combination of the two. Unfortunately, these models give contradictory conclusions, along with the result, that the core can be empty or not unique.

An alternative to "conjectures" and axiomatic approaches is an extensive form game approach. Under this approach, the formation of coalitions is seen as a sequential process, whereby players foresee the reactions of outsiders on their cooperation. In the extensive form framework, Ray, Vohra (1996, 1999) first proposed to derive both an equilibrium coalition structure and payoffs of players endogenously. In addition, the authors introduced a new assumption, which became fundamental in PFF modelling. They suggested transfers are allowed within coalitions, but not across coalitions, and that members of each coalition play cooperatively so as to maximize the value of the coalition, while different coalitions engage in a non-cooperative game.

However, most of the extensive form approaches also appear to have a drawback: the outcome of the game is strongly dependent on the protocol of the game. The protocol defines the order in which players make proposals and corresponding responses in a coalition formation process. In an attempt to overcome the dependency on protocol, endogenous order (Brown and Chiang [2003]) and random order models (Montero [1999], Gomes (2001, 2005)) were offered. Brown and Chiang (2003) found out that to solve the endogenous order game, in which players first bargain on who will be a proposer, transfers across coalitions must be allowed. However this violates the fundamental assumption of PFF games. In the course of her analysis of a random order game, where the proposer is chosen at random, Montero (1999) had to assume that once a coalition is formed it exits a game to rule out cycling. To illuminate this restriction, Gomes (2001, 2005) has offered a dynamic model in which players continuously renegotiate coalitions until all gains from cooperation are exhausted. Finally, Bloch and Gomes (2006) combine the features of different models and allow for endogenous exit of coalitions from the coalition formation and bargaining process.

For our analysis, we adopt a different solution concept, which has been recently proposed by Maskin (2003). In this approach, the players negotiate sequentially and the game is described in an extensive form. However, in contrast to protocol games the solution of Maskin (2003), similar to the Shapley value, is characterized by a set of axioms. The axioms specify how players are allocated into coalitions and payoffs are determined. Unlike the other axiomatic solutions, the solution of Maskin (2003) does not presume that the grand coalition always forms and an equilibrium coalition structure is derived endogenously. In addition, Maskin (2003) proves that in the case without externalities, his solution yields the Shapley value. Hence, the approach can be thought as a generalization of the Shapley value for PFF games.

3.2.3 The model

To introduce the extensive form Maskin (2003) uses the random order bargaining procedure developed by Weber (1988). The procedure is commonly used in cooperative game theory to represent bargaining, in particular to depict the general solution concept - Shapley value (1952). Under random order bargaining, coalition formation is considered as a sequential process. The players enter the bargaining process one by one in some order $\theta = \{.., \theta_i, ..\}$, where θ_i gives the entry number position of a player i. When player i enters the game, he observes a partial partition P formed by his predecessors $j : \theta_j < \theta_i$. At each node of the game, represented by the pair (P, i), the new coming player chooses to join one of the existing coalitions or to start a new one. We will use a subscript to point out, which coalition the player joins: if player i joins $S \in P$ then $P \to P_{S \cup i}$. If the player sets a new coalition $P \to P \cup \{i\}$ we write $P_{\{i\}}$. Decisions on allocation are irreversible so that coalitions may only increase but not break apart.

Given the allocation, the player is assigned a payoff. The payoff depends on the partition function, the order, and the partial partition P, which has formed: $\psi_i(w, \theta, P)$. We will distinguish the equilibrium payoff vector $\psi^*(w, \theta)$ under the terminal equilibrium coalition structure $P^*(\theta)$ given the order θ and a payoff vector $\psi(w, \theta, P^N)$ corresponding to some terminal partition P^N. To simplify notation we will omit the argument w in the payoff function assuming that a partition function is given.

The overall solution is obtained as a randomization over all possible θ. Following Maskin (2003), we assume the orders of players to be equally probable $Pr(\theta) = 1/|N|!$ and calculate the expected payoff vector of the game as:

$$E[\psi_i^*] = \sum_{\theta \in \Theta} \frac{1}{|N|!} \cdot \psi_i^*(\theta) \tag{3.2}$$

The probability distribution for the equilibrium partition is obtained as the probability weighted collection of $P^*(\theta)$.

Maskin (2003) accepts the fundamental assumption that players cooperate within and play non - cooperatively across coalitions. This property is expressed in the first axiom:[1]

(i) the sharing of joint profits within each coalition should be Pareto optimal for any terminal partition

$$\sum_{i \in S} \psi_i(P^N) = w(S; P^N) \text{ for } \forall S, P^N \tag{3.3}$$

where $\psi(P^N)$ is the payoff vector given some partition of players P^N. The axiom requires that coalitions distribute their profits fully among their members. This condition is sometimes called "budget-balancing" and was justified by Aumann and Dreze (1974) and Hart and Kurz [1983].

Maskin (2003) applies backward induction to solve the extensive form game. To that end, he formulates the second axiom, which states consistency, or sequential rationality, of the equilibrium outcome as follows:

(ii) for any i and partial partition P, if i is assigned to $S \in P$ and $S \cup i \subseteq S^*$

[1] In the course of the paper we change the original sequence of the axioms by Maskin (2003). We start with the axioms describing the properties of the solution common to other PFF solutions, and then formulate the specific to Maskin (2003) ones.

where $S^* \in P^*(\theta)$, then the equilibrium partition $P^*(\theta)$ resulting from P is the same as the one resulting from $P_{S\cup i}$, and so is the payoff vector $\psi^*(P^*(\theta)) = \psi^*(P^*_{S\cup i}(\theta))$

There remain two questions to be answered: to which coalition is a player allocated and how are payoffs to players determined? The answers are specific to Maskin (2003) and are the essence of his solution. By his third axiom, Maskin (2003) demands efficiency of a players' allocation: a player joins the coalition such that his allocation has the greatest impact on the profit of this coalition. The impact of the player's allocation also reflects externalities. It is a relative measure and corresponds to a particular alternative. Namely, it is presented by the gross marginal contribution of a player to a coalition S given the alternative coalition $S^{'}$, that is how much a profit of S changes if the player instead of joining this coalition will join $S^{'}$: $w(S \cup i; P^N_{S\cup i}) - w(S; P^N_{S'\cup i})$. A positive contribution creates incentives for coalitions to attract the player, since they will lose otherwise.

The partition function w gives the worth of coalitions under all possible terminal partitions P^N. Yet, to continue with axioms for allocation and assignment of payoffs we need to know the values of the coalitions embedded in partial partitions. We denote them $\widetilde{w}(S; P)$. Since we solve the game backwards, we can determine the allocation and the payoff of the last player $l : \theta_i < \theta_l$ for $\forall i$ for all possible P^N knowing only w. Then, we can reduce a game to $N \setminus l$, and calculate the values of coalitions in partitions $P^N \setminus l$. For the coalitions not including l the value is $\widetilde{w}(S; P^N \setminus l) = w(S; P^N)$, for the coalition $S^{'} \in P^N : l \in S^{'}$ the $w(S^{'}; P^N \setminus l) = w(S^{'}; P^N) - \psi_l(P^N)$. Generalizing, for a partial partition P formed by $j : \theta_j < \theta_i$ we obtain:

$$\widetilde{w}(S; P) = w(S^N; P^N) - \sum_{i \in S^N \setminus S} \psi_i \tag{3.4}$$

$$\text{where } \; S^N \in P^N \;\text{ and }\; S \subseteq S^N$$

In words, the value $\widetilde{w}$ can be interpreted as an undistributed profit of a coalition S.

Now we proceed with the third axiom

(iii) each player is allocated to the coalition $S \in P$, to which his gross marginal contribution is greatest

$$\widetilde{w}(S \cup i; P_{S \cup i}) - \widetilde{w}(S; P_{S' \cup i}) \geq \widetilde{w}(S'' \cup i; P_{S'' \cup i}) - \widetilde{w}(S''; P_{S \cup i}) \quad (3.5)$$

$$\forall S'' : \quad S'' \neq S \qquad S' = arg \max_{S''} [\widetilde{w}(S'' \cup i; P_{S'' \cup i}) - \widetilde{w}(S''; P_{S \cup i})] \quad (3.6)$$

In words, of all possible alternatives $S^{''}$ one finds the one $S^{'}$, compared to which the allocation of i to S has the largest impact (3.6). The coalition S attracts the player if the contribution of the player to S with respect to $S^{'}$ is greater than to $S^{'}$ with respect to S.

In a competition for a new player coalitions should be able to offer him at least as much as the others are ready to pay. In the result, payoffs of players are defined as follows:

(iv) every player earns his opportunity payoff, i.e. the second greatest gross marginal contribution

$$\psi_i(P, \theta) = \widetilde{w}(S' \cup i; P_{S' \cup i}) - \widetilde{w}(S'; P_{S \cup i}) \quad (3.7)$$

3.2.4 Equilibrium

According to Maskin (2003) for any superadditive game (N, w) the solution, satisfying axioms (i)-(iv) exists. This claim is proved as Theorem 1. The proof is done by construction and is based on the case of $|N| = 3$. Maskin (2003) asserts that for $|N| > 3$ the result of the theorem holds as well. However, we have found that, in general, this is not true. We present our finding in the following proposition:

Proposition 4 *For a game in partition function form (N, w) with $|N| > 3$, a solution pair $(E[\psi^*], p(P^*))$ satisfying axioms (i)-(iv) may not exist*

We prove this proposition by an example, which is given in Appendix 4.4.

Furthermore, in Theorem 2, Maskin (2003) claims that if all externalities are non-positive the solution $(E[\psi^*], p(P^*))$ fulfilling the axioms (i)-(iv) is unique. Once again the proof is done by construction for $N = 3$. In the course of our analysis we have revealed that this claim is not necessarily valid for $|N| > 3$. We state this result as

Proposition 5 *For a game in a partition function form (N, w) with $|N| > 3$ in which all externalities are nonpositive, that is for any S, S_k, and S_j: $w(S;P) \neq w(S;P^{'})$, where $P \setminus S_k \setminus S_j = P^{'} \setminus \{S_k \cup S_j\}$, the solution $(E[\psi^*], p(P^*))$ may not be unique*

A proof by example is provided in Appendix 4.4.

In our study the number of players $N = 6$ and, according to propositions (4) and (5) we may encounter the problems of non-existence and multiplicity. Non-existence of an equilibrium is a conceptual problem since in this case it is not clear what the outcome of the game is.[2] There is no reasonably simple way to show in which cases an equilibrium always exists in general.[3] Fortunately, in our calculations we have not encountered the problem of non-existence. This is largely due to a specific property of our game. We formulate this finding in

Proposition 6 *For a game in a partition function form (N, w) with $|N| > 3$ the solution $(E[\psi^*], p(P^*))$ exists, if at any node (P, i) of the game there exist at most one coalition $S \in P$ for which it matters to which of the alternative*

[2] Note, however, that the solution of Maskin (2003) is not the only one susceptive to the non-existence problem. There are many others solutions, in particular, those based on a Nash equilibrium, in which an equilibrium may not exist.

[3] See Ikonnikova and Willems (2007) for a further discussion on possible refinements to overcome the problem of non-existence and sufficient conditions for an equilibrium to exist.

coalitions the new player is going to be allocated, so that

$$\widetilde{w}(S; P_{S' \cup i}) \neq \widetilde{w}(S; P_{S'' \cup i})$$

and for all other $\widetilde{S} \neq S$ *it holds true that*

$$\widetilde{w}(\widetilde{S}; P_{S' \cup i}) = \widetilde{w}(\widetilde{S}; P_{S'' \cup i})$$

We prove proposition (6) and discuss in more detail the properties of our game in Appendix 4.4.

As multiple equilibria are concerned, they do occur in the course of our analysis. However, this does not present a severe problem since the choice of an equilibrium does not change the outcome of the game. In our analysis, multiplicity occurs only when the contribution of a player to all coalitions is zero. According to axiom (iii) the player can then be allocated to any coalition. As the number of such cases is small, we have been able to check that the allocations and the payoffs of the other players do not depend on the allocation of that player. To avoid additional complexity in computations we apply a simple tie-breaking rule: we assign such a player to the coalition formed by the first player.

3.2.5 Partition function

Finally, we explain how we calculate the values of the partition function. In our application, we assume, that coalitions of the terminal partition play Cournot competition. Forming a coalition players combine their initial resources $k_S^0 = \sum_{i \in S} k_i^0$. Once the coalition structure has formed, coalitions simultaneously make their decisions on supply quantities q_S^* and on investments in additional capacities $k_S - k_S^0$ as to maximize coalitional profits π_S. Hence

$$\pi_S^* = \max_{q_S, k_S} p(\sum_{S \in P^*} q_S) q_S - tc(q_S) - I \cdot (k_S - k_S^0), \quad q_S \leq k_S \tag{3.8}$$

where $p(q)$ is the inverse demand function, $tc(q)$ - total cost of supply, and I - per unit investment costs. The solution of the optimization problem (3.8) will give us the values of the partition function $w(S;P^N) = \pi_S^*$ and total optimal capacity of the network $\sum_{S \in P} k_S^*$:

$$w(S;P^N) = \pi_S^*(q_{S_1}^*, .., q_S^*, .., q_{S_m}^*) \tag{3.9}$$

where the quantities do not exceed the capacities available to the coalition $q_{S_k}^* \leq k_S^*$.

3.3 Results

3.3.1 Values of partition function

We calibrate the model to reflect the situation around year 2005, as described in section 1.2. The resulting values of the partition function and some other results are reported in table 3.1.[4] In the table we provide the results for the two extreme cases.

In the upper part of the table, entitled "all options", we present the profits and equilibrium capacities for coalitions when the players take into account both the existing pipelines and all pipeline options. This variant corresponds to the ultimate case in which all players are farsighted. In the lower part of the table, entitled "status quo", we assume that the players consider only the installed capacities. Hence, the figures reflect a shortsighted view. The complete table, with various investment options taken into consideration, is given in Appendix 4.4.

The table is organized as follows. In the first column we list the coalition structures under which the network described by the following seven columns

[4] We perform all calculations using Mathematica 5.1. The source files are available upon request.

can be implemented. We denote the players using the first letters of their names, i.e. the set of players N=$\{r, u, b, t, a, i\}$ consists of Russia, Ukraine, Belarus, Turkmenistan, Azerbaijan, and Iran, respectively.[5] For simplicity, we indicate only essential coalitions, which include at least one producer, since only such coalitions may organize supply and earn positive profit. We do not show the allocation of transiters if they do not join a coalition with a complementary producer. Thus, for example, the first line of the table characterizes the situation where Russia and Turkmenistan form singleton coalitions. The second line presents the case in which Russia alone competes with the coalition formed by the Caspian players. The third line considers what would happen if Russia and Turkmenistan cooperate, while all the transiters remain separate.

The next seven columns, that follow the partition column, show the pipelines and investment options available to coalitions. We use the sign "-" to mark the pipelines, which can not be used or invested in under the given partition. If a particular pipeline option is available, but a coalition decides not to realize it, we write "0" in a corresponding cell. We distinguish the pipelines and options, which require the presence of Russia and Turkmenistan in a coalition to be used. The first five columns indicate the pipelines for which Russia is an essential player. To build TCP and Nabucco a coalition must include Turkmenistan.

In the last three columns of the table we report the price and coalitional payoffs in absolute and relative figures. The relative values are given compared to the profit of the grand coalition $\{N\}$. In the following discussion we mainly focus on the relative figures, since the absolute profits are sensitive to our quantitative assumptions. In contrast, the relative results are fairly robust, because a change of demand and supply parameters affects all coalitions in a similar way.

[5] We assume that Poland, as a member of the EU, can not obstruct the supply through Yamal pipeline. Therefore we do not include it into the list of players.

In the "all options" variant, Russia, being alone, may invest in North European Gas Pipeline. As long as Turkmenistan does not form a competing supply chain, Russia will build the 74bcm/a pipeline through the Baltic sea and obtain a profit of 4.6$bn or 57% of the profit of the grand coalition. In cooperation with Ukraine, under the partition $\{\{r, u\}, \{t\}..\}$, Russia will forgo investment in expensive NEGP. Instead it will upgrade the old Ukrainian system increasing the transport capacity to 85bcm/a. As a result the coalition of Russia and Ukraine will earn 6.5$bn. Hence, one additional player will give Russia a 23% increase in relative profit. If Russia cooperates with Belarus, it will use the existing capacities of Yamal 1 and install additional 52bcm/a of Yamal2. With the total capacity of 80bcm/a the coalition will earn 5.8$bn yielding 72% of the profit of the grand coalition. Altogether, Russia, Ukraine, and Belarus will use the capacities of Ukold and Yamal1 to supply 90bcm/a of gas to the European market and achieve a relative payoff of 82%. Thus, the second transit option increases the total profit less than the first.

If Turkmenistan joins the coalition of Russia, Ukraine, and Belarus, its worth will increase by 18 percentage points. Hence, the profit of the grand coalition can be achieved by four major players even without Azerbaijan and Iran. Turkmenistan will also increase the relative payoffs of coalitions $\{r, b\}$ and $\{r, u\}$ by over 10 percentage points. However, the contribution of Turkmenistan to the coalition of $\{a, i\}$ is more than three times greater under all the partitions. If Turkmenistan forms a competing coalition with the Caspian transiters, the profit of a coalition organized by Russia will drop. Thus, the competition with the Caspian players will reduce the profit of $\{r, b, u\}$ by a third down to become only 59% of that of the grand coalition. In this case, the cooperation with Turkmenistan will increase the worth of coalition $\{r, b, u\}$ by almost 70 per cent to 40 percentage points.

The situation is quite different in the status quo case, when we do not allow for the extension of the network. Russia on its own can not supply its gas and will earn nothing. Only in cooperation with Ukraine or Belarus, or both, can it transport its gas to the market and earn profit. By including the two transiters, Russia will increase its profit by 82 percentage points. This is large compared to a 25 percentage points increase under the "all options" variant. Turkmenistan even in cooperation with Azerbaijan and Iran will have a zero profit. The Caspian producer will contribute only to a coalition including Russia and at least one transiter, Ukraine or Belarus. Turkmenistan will increase the profit of the three major players $\{r, b, u\}$ again by 18 percentage points, but this time it will have no other options to generate profit.

3.3.2 Strategic value of pipelines

Now we proceed with the analysis of the balance of bargaining power and strategic value of investment options. Based on the values of the partition function we find equilibrium coalition structures and the players' expected payoffs. In addition, we calculate a relative share of a player in the profit of the grand coalition. We interpret this share as the relative bargaining power of the player. The results of our computations are presented in table 3.2. The table consists of two parts presenting the two perspectives on bargaining: *shortsighted* and *farsighted*.

The upper part of the table, starting with the "status quo" variant, corresponds to a shortsighted view on the balance of power in the network. In this variant only the existing capacities of Ukold and Yamal 1 matter. Therefore, under the shortsighted view Russia forfeits almost half its gas export profits to the transiters. The sharing of the profit between the transiters reflects their unequal capacities. Ukraine has more than twice as much capacity as Belarus and obtains a three times greater share of profit.

In contrast, in a long-term perspective, the farsighted view, the players may build any pipeline. Hence, all options to extend the network are to be taken into account. In the lower part of the table we show the results of bargaining when all investment options are available. The picture changes significantly.

In the "all options" variant the producers gain almost 20 percentage points in power and increase their power by a third. At the same time, the transiters lose their advantage in a competition for transport services. Altogether they are left with only 22% of the profit of the grand coalition.

The comparison of "status quo" and "all options" variants reveals the impact of investment options on bargaining. To single out the value of a particular investment option, we examine how the relative shares of the members of the Eurasian gas supply network change with the availability of pipeline options. In the upper part we look at how the bargaining power changes if an investment option is added to "status quo". For example, after Russia and Germany agreed on building NEGP, Russia used this option as a bargaining chip in negotiations with Ukraine and Belarus. Thus, the project affects the power structure, although the capacities will not be installed until 2010. In the lower part of the table we consider the effect of removal of an investment option from the portfolio of options. Adding or withdrawing options is first of all a theoretical exercise to understand the strategic relevance of the different pipelines. It may, however, have a practical interpretation as well. For instance, an armistice in Georgia or Azerbaijan may prevent the TCP project from being implemented. If relations with Iran strain further, the Nabucco project may become politically unfeasible. The hold-up problem with Ukraine or Belarus, may induce Russia to back away from Upgrade and Yamal2 projects.

Considering various conjectures, we construct table 3.2. We use the name of the variant to indicate which investment option is added or withdrawn from the consideration. We compare "+" and "-" option variants to infer the significance of the investment option. In what follows we proceed with the analysis of our results.

Upgrade is the most efficient investment option and may increase the network capacity by 15bcm/a. Comparing the figures in the "+ Upgrade" and the "status quo" columns one can see that the option brings a slight shift in the profit sharing. Ukraine strengthens its bargaining position by less than one point. The option hardly affects the position of Russia, who strengthens its position by 1% at the expense of Belarus. The strategic role of the *Upgrade* is also negligible in the context of all the other options. The change in the power structure between "- Upgrade" and "all" is negligible, the option does not change the bargaining power of players except for Belarus. The relative shares of Russia and Ukraine decrease by less than 1%. The positions of other players remain unaffected. Hence, we can conclude that Upgrade turns out to be of no strategic importance to the players of the network.

The strategic role of the Yamal2 project is more vivid. If the option is added to status quo, it strengthens the bargaining position of Belarus and Russia. Ukraine loses 13 percentage points, while Belarus enjoys a 6 point increase in shares. The increased substitutability between the transiters confers Russia 6 points profit. However, the strategic value of the option decreases if it is considered in the context of all the options. With Yamal 2 available, Russia and Belarus gain 1 percentage point at the cost of Ukraine. To sum up, the investment option along Yamal has a small impact in the long-run and gives moderate strategic advantage to Belarus and Russia in the short-run perspective. This may explain the little interest of Russia in the track.

In contrast, the North European Gas pipeline changes the bargaining situation dramatically, from both the shortsighted and farsighted points of view. The pipeline is the most expensive of all. By our conservative estimate, it is about four times more expensive than the renovation of the Ukrainian system and it has long been considered to be commercially inefficient. However, it allows Russia to bypass its transiters and hence, damages the bargaining positions of the transiters. In comparison with "status quo" Russia increases its share in the profit by half, the share of Ukraine and Belarus is reduced to a third. Together the transiters will obtain 14% instead of 41% if NEGP is included. The great impact of NEGP on the balance of bargaining power can also be observed in the lower table. Once the option is added to the list of investment opportunities, Russia gains 1.5$bn or 17 percentage points in bargaining power. NEGP gives Russia a great strategic advantage in bargaining. This explains why Russia considers the pipeline as a highly beneficial project. The project, which seems to be commercially inefficient in comparison with Upgrade and Yamal2, brings Russia more profit than the other two projects together.

The options to increase transport capacities to supply Russian gas do not have a significant impact on the shares of the Caspian players. Turkmenistan has a weak bargaining position vis-a-vis Russia, as long as it cannot market its gas directly. However, TCP and Nabucco allow the producer to strengthen its position substantially. Like NEGP for Russia, the pipelines, bypassing Russia and opening an access to the European market, are of great strategic importance for Turkmenistan. Not surprisingly, the relative power of Turkmenistan increases by 3 times compared to status quo, from 0,5\$bn to 1.7\$bn, when the two pipeline options are accounted for. The threat of competition forces Russia to give up 15% of its total profit to Turkmenistan. The prospect of competition reduces the value of the whole supply chain including Ukraine and Belarus. The two transiters forfeit 14 points to newly emerged transiters - Azerbaijan and Iran. The strategic value of the Caspian pipelines remains considerable also in the context of "all" the options. Altogether the Caspian players gain 21 percentage points. The advantage in bargaining yields the profit of 1.5\$bn. This explains why the Caspian players are so enthusiastic about the new pipelines, even though the projects are costly. On the other hand, Russia loses almost 30% of its profit, its share decreases from 80% to 58%. Therefore, Russia is interested in preventing Turkmenistan from developing the alternative path.

3.3.3 Equilibrium partitions

For each variant introduced in table 3.2 we find the probability distribution of equilibrium partitions. The game between the network players includes only negative externalities, therefore, we expect the grand coalition to form. Transiters tend to join a complementary producer, since he benefits from their capacities at most. Supply chains are more profitable if integrated into one network, rather than competing against each other. Hence, the producers have incentives to cooperate and form a monopoly. As a result, in equilibrium the grand coalition is likely to form.

Looking at the equilibrium partitions predicted by the axioms (i)-(iv) we also find the support for the formation of the grand coalition. The values of the partition function confirm the efficiency of the grand coalition. The profit of any coalition including both producers $S_r \cup S_t$ is higher, than the sum of profit of coalitions S_r and S_t, when the producers stay separate. A contribution of Ukraine and Belarus to coalition S_r is higher than to S_t. Let's consider the partition $P = \{\{r\}, \{t, a, i\}, ..\}$. If Belarus joins $\{t, a, i\}$ Russia loses 1.2$bn, while the Caspian players gain only 0.1$bn in "all options" variant. Similarly, the contribution of Ukraine to a coalition of Russia is 1.4$bn vs. a zero increase in the profit of coalition $\{t, a, i\}$. Hence, according to axiom (ii) the transiters will join Russia. The possibility to build TCP and Nabucco is the most valuable for Turkmenistan. Under partition $P = \{\{r\}, \{t\}, ..\}$ Turkmenistan will achieve the profit of 3.1$bn with Azerbaijan and Iran, whereas if the transiters join Russia their contribution will be 1.4$bn. As a result, Azerbaijan and Iran will join Turkmenistan. Similar conclusions hold if $S_r = \{r, u\}$ or $\{r, b\}$. The allocation of the Caspian transiters has a greater impact on the coalition of Turkmenistan.

In the numerical calculations we find that the grand coalition forms with the probability 1 in all the variants with some negligible exceptions. In some orderings in variants "all minus one option", with the probability of less than 0.01 Azerbaijan and Iran stay separate. These orderings are such that the Caspian transiters start the coalition formation process. In most of these cases the formation of partitions $\{\{a\}, \{r, t, b, u, i\}\}$, $\{\{i\}, \{r, t, b, u, a\}\}$, and $\{\{a, i\}, \{r, t, b, u\}\}$ results from our tie-breaking rule. For the other cases, we can explain the fact that Azerbaijan and Iran are left outside the coalition as follows. According to the axioms by Maskin (2003), a player initiating a coalition will obtain the cooperation surplus, while the players joining the coalition after him receive only their opportunity payoff. In order to avoid giving up a share in coalitional profit to players who come first but contribute nothing to the coalition finally formed, a follower may decide to start a new coalition. The grand coalition will forego the expensive investments in TCP and Nabucco projects. Therefore, the four major players $\{r, t, b, u\}$ will start a new coalition if they enter the game after a and/or i.

3.3.4 Robustness

As already mentioned, values of the partition function are sensitive to our quantitative assumptions. As discussed in chapter 1 our estimations suffer from the lack of data and uncertainty. Gas prices, to large extent, reflect the movements in oil prices and may vary considerably during a period. The demand for FSU gas also depends on the ability of European customers to substitute it with the gas from other sources or with other sources of energy. The question arises: how robust are our numerical results on bargaining power to changes in our assumptions on demand parameters? We also note that NEGP, TCP, and Nabucco options have the greatest impact on the power structure. Would an increase in investment costs of these pipelines have a strong effect effect on the bargaining power of the players?

To check the robustness of our results we examine three changes in our assumptions: (i) a higher demand, (ii) a lower elasticity of demand, (iii) higher investment costs.

We show how the results change in the "all options" case in table 3.3. We consider a very substantial upward shift of demand increasing equilibrium supply and required transport capacities by 45%. As a result, the grand coalition will invest in additional 15bcm/a of Upgrade and 28bcm/a of Yamal 2. We find that higher demand diminishes the role of the existing capacities: Ukraine loses almost 50% of its relative power, the relative share of Belarus decreases by about 25%. At the same time the bargaining power of the producers increases: Russia gains 3 percentage points, the relative power of Turkmenistan rises by a third. The considerable change in the bargaining power of Ukraine and Turkmenistan reveals some sensitivity of our results to demand parameters.

A decrease of elasticity changes the power structure, but not significantly. Low elasticity demand compensates high costs of bypass options and strengthens the bargaining position of the producers. Turkmenistan obtains a share by 16% larger than in our original variant. The bargaining power of Russia changes by 1 percentage point. The relative share of Belarus and Ukraine decrease by 25%. Altogether we find that the difference with our base line results is minor.

Finally, we consider what happens if we increase investment costs of NEGP, TCP, and Nabucco by 50%. Intuitively, the more expensive the bypass options are, the smaller the bargaining power of the producers and the greater is the impact of existing pipelines. According to our calculations, Russia and Turkmenistan lose about 10% of their relative share, while Ukraine and Belarus almost double their shares. We conclude that a significant change in investment costs will affect our results.

3.4 Empirical evidence

In general it is difficult to analyze real world problems using partition function form games. The optimization problem of every conceivable sub–coalition of players has to be solved and the number of possible coalitions grows rapidly as the number of players increases. Many of the possible sub–coalitions would have to deal with situations which are very different from those prevailing in reality. This raises the problem of obtaining data and making predictions for rather hypothetical situations, which severely limits the practical applicability of the approach. Hence, the Eurasian gas supply network provides us with a rather unique opportunity to apply game theory. The number of truly independent players is small and the profits of the various coalitions can be derived with a reasonable accuracy.

In the paper we have demonstrated how bargaining power can be assessed. We have shown the effect investment options have on the strategic positions of the players. Nevertheless, it is difficult to relate our results to real world data. These are scarce as many terms of contracts are confident. Besides, given that the payoffs among players are sometimes made in kind or in the form of political concessions, it would be incorrect to compare our figures with profits, which countries obtain from gas export. Notwithstanding these difficulties, we can provide some rough estimates, which suggest that our model describes the situation quite well.

Currently, about 120bcm/a of gas is exported by Russia to Eastern and Western Europe through Ukraine. For the transit services Ukraine obtains a transit fee, which is about 20.2$/tcm and gas on a reduced price. Until 2005 Ukraine bought about 25bcm/a paying only a quarter of the prices of Europe. In terms of the supply profit, this amounts to 15% of Russia's profits from export via Ukraine, which is 70bcm/a, or around 10% of the total profit. Together with the transit fee this results in slightly less than 26% in total profit. In 2005, after Russia finally agreed to build NEGP in cooperation with Germany, it renegotiated the terms of its export to Ukraine and signed a new contract. According to the new deal, Ukraine had to pay the price equal to a third of the European level prevailing at that time. This weakened Ukraine's position to 14%. At last, in 2006 Russia and Ukraine signed a long-term contract, according to which the price increased to half of that of Europe. The contract envisages a full market price by 2010. Hence, at present Ukraine receives about 10% of the total export profit. Looking at table 3.2 we see that there is a reasonably close correspondence between the real changes in bargaining power of Ukraine and our results. Before the building of NEGP was approved, the bargaining position of Ukraine can be described by "status quo" variant. The current share of Ukraine coincides with "+NEGP" scenario. Russia's prospects to set the gas price for Ukraine to the European level and hence, leave it slightly more than 6% of total profit, corresponds to allocation of bargaining power in "all" scenario.

Russia has also asked a price increase for its export to Belarus. After continuous negotiations, Belarus has recently given up to Russian demands under the treat of being cut off. Now instead of one fourth, the transiter pays a half of the European prices. In total this counts for a decrease in the total profit share of Belarus from 12% to 3%. This change can be associated with the shift from "+Yamal2" variant to "+NEGP" or "all" scenario.

Unfortunately, we can not say much about payoffs of the Caspian transiters. Some information is available only on a payoff to Turkmenistan. Soon after tentative agreements have been signed and negotiations about a financial support of the TCP and Nabucco projects with the USA and EU have been initiated, Russia doubled its payments to Turkmenistan for gas. Now Russia pays for Turkmen gas half of the European prices. Only one year ago it paid less than a third. It is difficult to separate how much of the gas bought from Turkmenistan Russia actually sells to Europe. The estimates range from 10bcm/a to 20bcm/a. In addition Russia buys gas to deliver it as a transit payment to Ukraine. Altogether the final payment for Turkmenistan in the past was about 5%, which roughly coincides with its share in the "status quo" variant. However, under the new contract, in which Russia agreed to double the price for Turkmen gas and increased its import, the bargaining position of Turkmenistan improved. The new share of the Caspian producer can be estimated around 10% to 12%. Hence, we again observe a transition in the direction of the "all options" variant.

We conclude that our model allows to explain developments in the Eurasian gas supply network quite well. Our results are correct by order of magnitude and reflect the trend by direction. Apparently, a shortsighted view on a bargaining power changes only after an option has been formally approved and the project is close to realization. The short-term agreements seem to reflect the existing capacities only, whereas terms of long-term contracts reflect a farsighted view.

Table 3.1: Production plans, prices, and profits

partition	capacity on pipelines bcm/a							price	profit	% of total
	Uold	Yam1	Yam2	Uup	NEGP	TCP	Nab	\$/tcm	\$bn	
all options										
$\{\{r\},\{t\},..\}$	-	-	-	-	74	-	-	145	4.6	57%
$\{\{r\},\{t,a,i\},..\}$	-	-	-	-	61	30	30	129	3.2; 3.0	39%; 37%
$\{\{r,t\},..\}$	-	-	-	-	89	-	-	142	5.7	71%
$\{\{r,b\},\{t\}..\}$	-	28	52	-	0	-	-	143	5.8 1	72%
$\{\{r,b\},\{t,a,i\}..\}$	-	28	38	-	0	30	30	125	4.0; 3.1	50%; 38%
$\{\{r,t,b\},..\}$	-	28	68	-	0	-	-	136	7.0	87%
$\{\{r,u\},\{t\}..\}$	70	-	-	15	0	-	-	141	6.5	81%
$\{\{r,u\},\{t,a,i\}..\}$	70	-	-	0	0	30	30	124	4.6; 3.0	57%; 37%
$\{\{r,t,u\},..\}$	70	-	-	15	6	-	-	139	7.7	92%
$\{\{r,b,u\},\{t\}..\}$	70	20	0	0	0	-	-	141	6.6	82%
$\{\{r,b,u\},\{t,a,i\}..\}$	70	5	0	0	0	30	30	121	4.7; 2.9	59%; 30%
$\{N\}$	70	28	0	0	0	0	0	135	8.1	100%
status quo										
$\{\{r,u\},\{t,a,i\}..\}$	70	-	-	-	-	-	-	147	6.3	79%
$\{\{r,t,u\},..\}$	70	-	-	-	-	-	-	147	7.2	90%
$\{\{r,b\},\{t,a,i\}..\}$	-	28	-	-	-	-	-	164	3.5	44%
$\{\{r,t,b\},..\}$	-	28	-	-	-	-	-	164	3.7	46%
$\{\{r,b,u\},\{t,a,i\}..\}$	70	20	-	-	-	-	-	139	6.6	82%
$\{N\}$	70	28	-	-	-	-	-	135	8.1	100%

[a] The demand function $p(q)$=175 - 0.4q and the production cost of Russia $ac_r(q)$=25+0.4q and of Turkmenistan $ac_t(q)$=20+0.3q are chosen as to make existing capacities 70bcm/a of Ukold and 28bcm/a of Yamal1 be optimal.

Table 3.2: Payoffs in $bn and bargaining power w.r.t. availability of pipelines

	status quo		+ Upgrade		+ Yamal2		+ NEGP		+ TCP		+ TCP&Nab	
Russia	4.3	53%	4.4	54%	4.8	59%	6.3	78%	3.5	43%	3.0	37%
Turkmenistan	0.5	6%	0.5	6%	0.5	7%	0.6	8%	1.2	15%	1.7	21%
Ukraine	2.4	31%	2.5	31%	1.5	18%	0.8	10%	1.9	24%	1.6	20%
Belarus	0.8	10%	0.7	9%	1.3	16%	0.3	4%	0.7	9%	0.7	8%
Azerbaijan	0	0%	0	0%	0	0%	0	0%	0.7	9%	0.5	7%
Iran	0	0%	0	0%	0	0%	0	0%	0	0%	0.5	7%

	all options		- Upgrade		- Yamal2		- NEGP		- TCP		- TCP&Nab	
Russia	4.7	58%	4.7	58%	4.6	57%	3.3	41%	5.4	67%	6.5	80%
Turkmenistan	1.6	19%	1.5	19%	1.5	19%	1.7	21%	1.1	14%	0.7	8%
Ukraine	0.7	8%	0.6	8%	0.9	10%	1.2	15%	0.7	8%	0.7	8%
Belarus	0.3	4%	0.4	5%	0.2	3%	0.9	11%	0.3	4%	0.3	4%
Azerbaijan	0.4	5%	0.4	5%	0.4	5%	0.5	6%	0.5	7%	0	0%
Iran	0.4	5%	0.4	5%	0.4	5%	0.5	6%	0	0%	0	0%

Table 3.3: Robustness

	original variant[a]	high demand[b]	low elasticity[c]	high costs[d]
Russia	58%	61%	59%	56%
Turkmenistan	19%	25%	22%	15%
Ukraine	8%	4%	6%	14%
Belarus	4%	3%	3%	6%
Azerbaijan	5%	4%	5%	4%
Iran	5%	4%	5%	4%

[a] $p(q)$=175 - 0.4q $ac_r(q)$=25+0.4q $ac_t(q)$=20+0.35q $\epsilon(100)$=-3.4

[b] $p(q)$=250 - 0.4q $\epsilon(100)$=-5.2

[c] $p(q)$=190 - 0.55q $\epsilon(100)$=-2.4

[d] investment costs of NEGP, TCP, Nabucco are increased by 50%

Chapter 4

Coalition formation, commitment, and strategic investments

4.1 Introduction

In 2005 Russia started to build the North European Gas Pipeline, the first direct pipeline to Europe and the most expensive one of all. Why has Russia forgone cheaper investment options? Similarly, over the last five years Turkmenistan and other Caspian countries have considered expensive pipelines, Trans-Caspian and Nabucco, to reach European markets bypassing Russia. Although little progress has been made, the projects are continuously discussed in the press. Why do the Caspian players keep these options? Are they actually going to realize them?

In this chapter we develop a model to answer these two questions. We build a framework to analyze multinational relations and understand distortion of investments in the Eurasian gas supply network. We continue the analysis provided in chapter 2 and 3. Like in chapter 2 we consider how the hold-up problem may affect investments in pipelines. We again assume that the players are heterogenous in their ability to make long-term commitments and are prone to renegotiate ex post. As in chapter 3 we include the Caspian Republics into the list of network players. Hence, in contrast to the model in chapter 2, competing supply chains may be formed resulting in externalities across coalition. Therefore, we have to extend the framework developed in the previous chapter to allow for externalities and the hold-up problem.

As in chapter 2 we use a two stage model to represent the hold-up problem. At the first stage players form coalitions to invest and bargain over investment and profit sharing. At the second stage investment costs are sunk, players cooperate or compete to supply gas to the market. We assume that supply coalitions formed at the second stage compete in prices given the capacities installed at the first period. Reliable players can commit not to renegotiate the agreement of the first stage. Unreliable players cooperate at the first stage to attract investments, but will renegotiate at the second stage to get a higher share of profit.

On each stage we have to solve a game of coalition formation and bargaining similar to the one presented in section 3.2. We again represent a game in "partition function form" and solve it using the solution concept of Maskin (2003). In the quantitative part we follow the assumptions presented in section 1.2 and numerically solve for equilibrium coalition structures, expected payoffs of the players, and investments. We consider three scenarios, which vary in the assumptions on the players' ability to commit. As a benchmark case we take the situation in which all the players can credibly commit. The resulting first best investment would maximize the profit of the whole network. The second scenario describes the situation where only producers, Russia and Turkmenistan, can commit, while transiters are prone to recontract. In the third scenario none of players can commit.

We find, that the hold-up problem leads to overinvestment, as well as underinvestment, and "undercooperation". Underinvestment occurs when investment in a cost efficient pipeline weakens the bargaining position of a producer too much. Overinvestment occurs when investment in expensive pipelines, while reducing overall profits, yields a large enough gain in bargaining power. In other words, players increase capacities to strengthen their bargaining position vis-a-vis unreliable partners. By undercooperation we mean a more splintered coalition structure compared to the one which would prevail if all the players can commit.

It turns out that the ability to commit to long-term profit sharing is of an overriding importance and diminishes the role of investment cost. In the second scenario, when the transiters cannot commit, the producers cooperate at the investment stage and invest in expensive direct pipelines. The resulting overcapacity is justified by a bargaining advantage of the producers at the second stage. Yet if we assume that the producers were also not able to commit, competing supply coalitions form. The Caspian producers would build the pipelines bypassing Russia, in spite of the assumed unreliability of the Caspian transiters. Russia would still build the direct Baltic pipeline. The lack of commitment would substantially reduce the profit of the network.

Among other works mentioned in the previous chapters, the analysis of this chapter relates to the investigation by Harbaugh [2001]. Harbaugh [2001] studies effects of the hold-up problem on investments of firms organized in coalitions by equity stakes. He considers two firms, a target firm and a shareholder firm. First, a target firms sells rights on its profit, then both firms can make investments affecting both sides' profitability and finally the two firms bargain over the division of the joint profits. Examining the ex post bargaining between firms, Harbaugh (2001) finds, similar to Janeba [2000], that the commitment problem may result in underinvestment and overinvestment as the firms attempt to improve their bargaining positions. Although the framework of Harbaugh [2001] is somewhat similar to ours, his model is constructed for the two player case, whereas we present a solution suitable for any number of players.

The remainder of the paper is organized as follows. Section 2 presents a formal modal. In Section 3 we consider the results and suggest their interpretation. Section 4 concludes.

4.2 The model

4.2.1 Basic notions

To analyze the investment problem we use a two stage model. We consider a set of players $N = \{.., i, ..\}$ consisting of producers and transiters cooperating to sell gas. Gas is transported through pipelines. Before trade takes place the players set up capacities by investing in pipelines. Players may form coalitions to invest cooperatively. By the time of supply, investment costs are sunk and capacities generate quasi-rents. Before implementing the investments, members of coalitions sign long-term contracts specifying how expected rents are to be shared. We assume that some players may be not able to credibly commit to such contracts and may renegotiate payoffs ex post. Hence, the "hold-up" problem may arise. As a result, only credible players will cooperate to invest.

In detail the game unfolds as follows. At the first stage, marked with the superscript I, players form "investment coalitions" S^I. The set of coalitions $P^I = \{.., S^I_k, ..\}$ is referred to as a *partition*, or a coalition structure.[1] In view of the hold-up problem we limit the set of possible coalition structures by allowing only the set of credible players N^c to form coalitions. The players, who cannot credibly commit $N \setminus N^c$, play as singletons. We denote the new set of partitions formed within this restriction as Π^I. Note that Π^I is a subset of the set $\mathbf{P}^I$ of *all* possible coalition structures that can be formed by

[1] Here we will use the same partition function form approach and imply, the same properties of the game as in the previous chapter. In particular, coalitions embedded in any partition are pairwise disjoined $S_k \cap S_h = \emptyset$ for all $k \neq h$ and $\bigcup_{k=1}^{|P|} S_k = N$, where $|\cdot|$ denotes cardinality, e.g. $|N|$ is the total number of players.

the players N. The two sets are equal if all the players can commit $\Pi^I = \mathbf{P}^I \Leftrightarrow N = N^c$, if none of the players can commit $N^c = \emptyset$ the only possible partition is a set of singletons $\Pi^I = \{N\}$.

Each coalition $S^I \in \Pi^I$ invests in network capacities $k^*(S^I)$ to maximize its future rent $w^I(S^I; \Pi^I)$. The rent depends on the total capacity of the network and hence on the entire partition. Therefore, we use a partition function for its representation. Members of S^I bargain between themselves over the rent sharing and fix the payoffs $\psi^I = (.., \psi_i^I, ..)$ with long-term contracts. Overall, at the first stage the coalition formation and bargaining game is given by (N, N^c, w^I). The solution of this game is a vector of expected payoffs $E[\psi^I]$ and a probability distribution of equilibrium partitions $p(\Pi^I)$.

At the second or "supply" stage, investment costs are sunk, the network capacities $k^* = \sum_{S^I \in \Pi^I} k^*(S^I)$ are fixed and players form coalitions S and supply to the market. We use the superscript S to label the variables of the second stage.[2] At this stage the set of players is represented by coalitions Π^I formed at the previous stage of our model. In other words each coalition S^I acts as a single player. We denote the coalition structure at the second stage as P^S. Newly formed coalitions S compete on the market setting prices p_S and quantities q_S. The market equilibrium depends on the set of suppliers P^S and profits, which are again given by a partition function $w^S : (S; P^S) \to R$. Within coalitions players bargain over sharing of the supply profits. The outcome vector of payoffs $\psi^S = (.., \psi_{S^I}^S, ..)$ determines the rents of the first stage coalitions. In short, the second stage is described by the game in partition function form (Π^I, w^S). The outcome of the game is the pair $(E[\psi^S], p(P^S))$ - the vector of expected payoffs and probability distribution of coalition structures.

By its structure, our two stage game is similar to a composite game devel-

[2] However, to avoid cumbersome notations we will denote coalitions formed at this stage as S instead S^S.

oped by Owen [1977]. Owen [1977] modeled a game, in which players form 'a priory' coalitions to gain an advantage in subsequent bargaining, where these coalitions act as units. He defined the expected payoff of a player as an outcome of the bargaining over sharing of the expected profit of an 'a priory' coalition, which the player joins. The approach of Owen [1977] is based on the Shapley value and hence, does not allow for externalities. We extend the framework of Owen [1977] to games with externalities by using the solution concept of Maskin [2003].

To solve the investment problem, we have to solve the game at the first stage (N, N^c, w^I). To this end, we must calculate the values of the partition function w^I. By analogy with the approach of Owen [1977], we work out the game backwards and first solve the bargaining game at the second stage (Π^I, w^S) for all possible equilibrium partitions of the first stage Π^I. We have described the approach in chapter 3 and in what follows we assume that we know how to find $(E[\psi^I], p(\Pi^I))$ and $(E[\psi^S], p(P^S))$ once the values of the partition functions are given. We proceed with the model backwards and start with the supply stage.

4.2.2 The second stage

At the second stage the capacities of the network $k^* = \{k_l^*\}_{l \in L}$ for $L = \{NEGP,\ Ukold,\ Upgrade,\ Yamal1,\ Yamal2,\ TCP,\ Nabucco\}$ are fixed. By forming a coalition players combine their resources. We denote the capacities that a coalition has at its disposal by $k^*(S)$.[3] The available capacities constrain supply: $q_S \leq k^*(S)$. In order to be able to supply a coalition must include at least one producer. In our case, we have only two producers, so that at most two supply coalitions can form. We assume coalitions compete in prices and use the insight of Kreps, Scheinkman (1983) to analyze

[3]Capacities available to a coalition are the pipelines running through the territories of the coalition members. For instance, Russia controls NEGP $k^*(\{r\}) = \{k^*_{NEGP}\}$, Ukraine - Ukold and Upgrade $k^*(\{u\}) = \{k^*_{Ukold}, k^*_{Ukold}\}$.

the price competition under capacity constraints. Each coalition sets a price and serves demand up to available capacities:

$$q_S = \begin{cases} \min[\, k^*(S), \max[0, D(p_S) - k^*(S^{'})]\,], & p_S > p_{S'} \\ \min[k^*(S), D(p_S)], & p_S < p_{S'} \\ \min[k^*(S), \max[\frac{D(p_S)}{2}, D(p_S) - k^*(S^{'})]\,], & p_S = p_{S'} \end{cases} \tag{4.1}$$

here $D(p)$ is the demand function and S and $S^{'}$ are the competing coalitions. The coalition, which sets a lower price, supplies first, high price coalition faces residual demand. Following Kreps and Scheinkman [1983] we assume the efficient rationing of demand. If the prices are the same, competing coalitions share the demand equally. If both producers are in the same coalition, they form monopoly. As a result, coalitions obtain a net profit $\pi(S; k^*(S), k^*(S^{'}); p_S, p_{S'}) = p_S q_S - tc(q_S)$, where $tc(\cdot)$ is the total cost of supply.

According to Lemmas 2 to 6 in Kreps and Scheinkman [1983] there can be a pure strategy and a mixed strategy equilibrium. The former occurs when the total capacity is in the Cournot region, that is smaller than the optimal Cournot response: $r(k^*(S^{'})) = arg\max_{k^*(S)} p(k^*(S) + k^*(S^{'}))k^*(S) - tc(k^*(S)) \geq k^*(S)$. In this case, coalitions earn Cournot profits. If $k^*(S) > k^*(S^{'})$ and $k^*(S) \geq r(k^*(S^{'}))$ there is a mixed strategy equilibrium, and the expected profit of a larger (in terms of capacity) coalition is equal to $\pi^*(S; k^*) = p(r(k(S^{'})) + k(S^{'}))r(k(S^{'})) - tc(r(k(S^{'})))$. The coalition with smaller capacities earns the expected profit of $k(S^{'})/k(S) \cdot \pi^*(S; k^*)$.[4] The equilibrium profits determine the values of the partition function:

$$w^S(S^S; P^S) = \pi^*(S; k^*) \tag{4.2}$$

For coalitions consisting of transiters only we have $w^S(S^S; P^S) = 0$.

Calculating the values of the partition function for all possible P^S, we obtain a full description of the game of the second stage, and can solve for the equilibrium $(E[\psi^S], p(P^S))$. Since the values of the partition function

[4]For more detail see Kreps and Scheinkman [1983].

depend on capacities, the outcome of the game also depends on k^*. To make this relation explicit we write $E[\psi^S(k^*)]$ and $p(P^S(k^*))$. Now we proceed with the first stage at which the capacities are chosen.

4.2.3 The first stage

At this stage players form coalitions and agree on a long-term rent sharing. Recall that by assumption some players can not commit and will recontract. As a result, only credible players can cooperate in coalitions, whereas the others will act as singletons. Anticipating their future payoff $E[\psi^S_{S^I}(k^*)]$ members of coalitions S^I invest as to maximize:

$$\pi^*(S^I;\Pi^I) = \max_{k(S^I)} E[\psi^S_{S^I}(k^o + k(S^I) + k(\Pi^I \setminus S^I))] - I(k(S^I)) \tag{4.3}$$

here k^o is the initial capacities of the network.[5] Coalitions choose investments $k^*(S^I)$ taking into account the decisions of the outsiders $k^*(\Pi^I \setminus S^I)$. To find the Nash equilibrium S^I for a given partition Π^I we solve the optimization problem (4.3) simultaneously for all coalitions embedded in Π^I. Repeating the procedure for all feasible Π^I we define the partition function:

$$w^I(S^I;\Pi^I) = \pi^*(S^I;\Pi^I) \tag{4.4}$$

Finally, applying Maskin's (2003) approach we determine how rents are shared within coalitions to find $(E[\psi^I], p(P^I))$. For the players who can not commit $E[\psi^I_i] = E[\psi^S_i(k^*)] - I(k(\{i\}))$. In essence we obtain our results applying a procedure similar to the one proposed by Owen [1977], but use Maskin [2003] solution instead of the Shapley value.

[5]Since a coalition can invest in any pipeline in the network, in contrast to $k^*(S)$, the vector $k^*(S^I)$ can include capacities which are not under the control of $i \in S^I$ at the second stage.

4.3 Results

For the calibration of the model we use assumptions on demand and supply motivated in chapter 1. As we are interested in the implication for current investment planning, we look at into the future and choose the high demand and high supply cost scenario to evaluate the partition functions w^I, w^S. From these we calculate the equilibrium coalition structures and the expected payoffs at the first and second stages. Finally, we solve for the equilibrium investments and find the resulting supply quantities.[6] We make these calculations for three scenarios, varying the assumption on who can commit to long-term profit sharing. The first scenario is a benchmark case, in which we assume, that all players can commit. In this case the hold-up problem does not arise and the first best strategy is chosen. We call this scenario accordingly - "first best". In the second scenario, titled "$\{r, t\}$", we assume that only Russia and Turkmenistan have the ability to make credible long-term commitments, while the transiters are prone to renegotiate their payoffs, after capacities are in place. Our third scenario, labeled "$\{\emptyset\}$", reflects the situation, in which none of the players can commit. Table 4.1 and Table 4.2 present the results.

For the first scenario we obtain that in equilibrium the grand coalition will be formed with a probability of 0.91 at the investment stage $P^I = \{N\}$. With a probability of 0.09 two competing coalitions will form $P^I = \{\{r, b, u\}, \{t, a, i\}\}$.[7] The grand coalition chooses capacities so as to maximize the network profit and install the pipelines with the lowest capacity costs. As it is shown in the first row of figures in Table 4.1, the players will invest in 15 bcm/a of Upgrade and 28 bcm/a of Yamal2. With 43 bcm/a of extra capacity, the total capacity of the network is 141 bcm/a which is equal to the profit maximizing supply quantity. Deducting annual investment cost in the amount of \$0.5bn, the players obtain a net profit of \$16.3bn. This

[6]Calculations are performed with Mathematica 5.1 program. Files with results are available upon request.

[7]With the probability less than 1% Azerbaijan and Iran will be left outside the coalition.

Table 4.1: Equilibrium investments, quantities, profits

scenario	extra capacity[a] [bcm/a]					$\sum_S q_S \parallel \sum_l \bar{k}_l$	$\sum_l I_l$	net profit[b]
	NEGP	TCP	Nab	Uup	Yam	[bcm/a]	\$bn	\$bn
first best[c]	0	0	0	15	28	141 ‖ 141	0.5	16.3
$\{r, t\}$	105	0	0	0	0	141 ‖ 203	2.6	14.0
$\{\emptyset\}$	87	30	30	0	0	141 ‖ 245	3.6	12.9

[a] Besides, there are two existing pipelines k_{Ukold} =70bcm/a and k_{Yamal1} =28bcm/a

[b] for demand p(q)=250-0.4q and supply costs ac_r=40+0.4q and ac_t=30+0.35q

[c] when the grand coalition forms

Table 4.2: Expected payoffs in \$mln

	first best[c]		$\{r, t\}$		$\{\emptyset\}$	
	ψ^I	$\widetilde{\psi^S}$	ψ^I	$\widetilde{\psi^S}$	ψ^I	ψ^S
Russia	10.2	8.6	10.0	12.7	8.6	10.8
Turkmenistan	3.5	1.0	3.4	1.4	2.1	3.5
Ukraine	0.8	4.0	0.3	0.9	0.2	0.2
Belarus	0.6	2.3	0.2	0.4	0.2	0.2
Azerbaijan	0.7	0	0	0	0.9	0.9
Iran	0.7	0	0	0	0.9	0.9

profit is shared among the players according to ψ^I as given in the second column of Table 4.2. If competing supply chains form, the coalition $\{r, b, u\}$ will invest in Upgrade and add 10bcm/a. The Caspian players will build both TCP and Nabucco with total capacities of 60bcm/a. However, at the second stage the grand coalition forms and the players use the capacities installed at the first stage efficiently and supply 141bcm/a. In the next subsection we will look in more detail why competing supply chains may form although players can commit.

To justify our next scenario, consider a thought experiment on what would happen if the players renegotiate after the capacities are installed. The second column of table 9, entitled $\widetilde{\psi^S}$, presents the result of such an imaginary ex post bargaining. One can see, that Ukraine and Belarus would benefit a lot from recontracting, since the additional capacities strengthen their bargaining position and enable them to extract more rent. Hence, in the absence of international institutions, which would enforce investment contracts, renegotiations are to be expected. This leads us to the next scenario.

4.3.1 Hold-up and distortions

Assuming that the transiters can not commit we obtain that at the first stage the partition $P^I = \{\{r, t\}, \{a\}, \{b\}, \{i\}, \{u\}\}$ will form with probability 1. As the second row of Table 4.1 shows, the producers will not implement Upgrade and Yamal 2, but will invest in the direct offshore pipeline. The North European Gas Pipeline will be built with a capacity of 105 bcm/a. At the supply stage the grand coalition will form, with the probability 0.99, and the optimal supply quantities will again be 141 bcm/a. As a result, 62bcm/a of new capacity will be left idle. With total investment cost of \$2.6bn, the net network profit will be \$14.0bn, that is much less than in the first best case.

As in chapter 2 the hold-up problem leads not only to underinvestment as commonly predicted, but also to overinvestment and excess capacities. The producers underinvest in cheap options in Ukraine and Belarus, and overinvest in NEGP. These "strategic distortions" of investments reflect the efforts of the producers to strengthen their bargaining position and gain leverage vis-a-vis unreliable transiters. NEGP will allow the producers to bypass all the transiters and hence, will grant them a great strategic advantage in bargaining.

To motivate the third scenario, we look at what would happen if the producers fall apart and recontract ex post. The fourth column in Table 4.2 gives the expected payoffs of the players in this situation. Since $\psi_r^I < \widetilde{\psi^S}_r$ we conclude, that now it is Russia who has incentives to renege on the agreement.

This leads us to the scenario "$\{\emptyset\}$" in which no player can commit. As the last row in Table 4.1 shows, in equilibrium NEGP, TCP, and Nabucco will be built with the capacity of 87 bcm/a, 30 bcm/a, and 30 bcm/a, respectively. We find that the players will form the grand coalition at the supply stage, with a probability of about 0.85. With a probability 15% two competing coalitions $\{r, b, u\}$ and $\{t, a, i\}$ will form. Columns five and six report the expected payoffs of the players. We obtain that in equilibrium only Russia and Turkmenistan will invest. Therefore, the expected payoffs at the supply and investment stages are the same for the transiters, while the payoffs of Russia and Turkmenistan are reduced at the investment stage by investment costs.

In the third scenario we again observe strategic distortions of investments, including underinvestment, overinvestment, and excess capacity. If the grand coalition forms at the supply stage, more than half of the new capacities will not be used. If the Caspian players form a separate coalition, capacities of TCP and Nabucco will be fully used to compete with Russian supply. Two thirds of the capacities along the Baltic sea will be left idle. Hence, the more players are not able to commit, the larger overinvestments are and the less likely the grand coalition be formed.

Considering the aggregate network profits given in the last column of Table 4.1 we evaluate the costs of the lack of commitment. The inability of transiters to commit to long-term rent sharing results in the loss of \$2.3bn, as the investment costs soar by almost three times, from \$0.5bn to \$2.6bn. Altogether, the lack of commitment, combined with the absence of any enforcement institution leads to the waste of over \$3.1bn annually.

4.3.2 Formation of competing coalitions

As we have mentioned above, under "all can commit" scenario, competing coalitions may form. Now we look at this phenomenon in more detail. First, note that the probability 0.09 means, that the partition $P^* = \{\{t,a,i\},\{r,b,u\}\}$ forms in 66 orders θ out of $|N|! = 6!$. We find that a distinguishing feature of these orders is that Russia enters the game only after all the Caspian players and Ukraine or Belarus have already arrived. Here, for illustrative purpose we consider the order $\theta : (t,a,b,i,u,r)$. Although the game is in fact solved backwards, we will discuss the moves in the natural order.

Azerbaijan as a second players has to choose whether to join Turkmenistan or start a new coalition. As we discussed in chapter 3, a transiter always joins his complement producer, hence $\{t,a\}$ forms. The next step, allocation of Belarus, is a turning point of a game. If Belarus joins $\{t,a\}$, the grand coalition will form, if the transiter starts a new coalition, then competing coalitions form. Let's assume that Belarus enters coalition $\{t,a\}$. By the next step Iran will join Turkmenistan, without whom it can not use his resources. Then Ukraine enters the game. We find that Ukraine will not join $\{t,a,b,i\}$, because the worth of its resources is diminished by presence of other transiters. Instead Ukraine will organize a new coalition, which Russia joins on the next step. Russia will prefer to join Ukraine, because as in the case of Ukraine, the value of its resources is smaller in the presence of Turkmenistan. Even without Russia, Turkmenistan can supply its gas via TCP and Nabucco, whereas the worth of a coalition of Ukraine without Russia is zero. Hence, we calculate that Russia's contribution to $\{u\}$ is larger than to $\{t,a,b,i\}$. To sum up, the partition $\{\{r,u\},\{t,a,b,i\}\}$ would form, if Belarus enters the existing coalition.

Coming back to the question of the allocation of Belarus, we see that if it joins $\{t,a\}$, its resources will be idle without Russia. Therefore, Belarus may prefer to start a new coalition. In this case, the choice of Iran does not change and $\{t,a,i\}$ forms. When Ukraine enters the game, it will join Belarus. In principle, it may start a new coalition $\{u\}$ or join $\{t,a,i\}$. Russia will prefer to follow Ukraine both in $\{\{t,a,i\}, \{u\},\{b\}\}$ in $\{\{t,a,i,u\},\{b\}\}$. However, neither of the two alternatives will give Ukraine a larger payoff, than in the $\{b,u\}$ case. Finally, Russia enters the game and joins the coalition of complement transiters forming $P^* = \{\{t, a, i\}, \{r, b, u\}\}$.

Similar reasoning is applied to $\emptyset$ scenario. Competing coalitions form at 108 orders at the supply stage. In these orders Russia, as in the example discussed above, arrives after the Caspian players. Thus, we revealed that the outcome of the game depends on the worth of resources of a player in the presence of other members of the coalition.

4.4 Conclusions

In this chapter we developed a framework for the analysis of endogenous coalition formation and multilateral bargaining in an environment with externalities. We applied our study to analyze the Eurasian gas supply network. Since there are no international institutions which could enforce contracts between the countries involved in the network, we assumed that a commitment problem may arise. Our calculations showed that the countries do be prone to hold-up in order to extract higher profits.

We looked at three different scenarios, varying the assumption on the players' ability to commit. Our results support the assumption that investments are mainly driven by strategic considerations and the desire to strengthen the bargaining position. As in chapter 2 we find that the "hold-up" problem may lead to underinvestments as well as overinvestments and excess capacities. The players underinvest in capacities of unreliable parties and overinvest in capacities which strengthen their bargaining position.

Applying the model to the Eurasian gas supply network we succeeded in providing a rational for observed investment patterns. We find that the ability to commit prevails over investment costs. In our analysis we obtain that whenever there is a possibility that Ukraine and Belarus will recontract, the North European Gas Pipeline will be built. The disputes between Russia and Ukraine and Belarus questioned the credibility of these countries and led to strategic distortions in investments: underinvestments in the upgrade of the Ukrainian system and the Yamal 2 pipeline. Both projects have been abandoned in favor of the expensive Baltic pipeline. The fact that investment in NEGP is under its way confirms our results. However, as to the amount for overinvestment our predictions appear to be too large. This result can be explained by the static nature of our model.[8] Recall that in our study we assume that the countries can invest, and hence, change their bargaining position, only once.

Furthermore, according to our results, the larger the number of players who can not commit, the larger is the overinvestment. If none of the players can commit, NEGP, TCP, and Nabucco will be built. This finding also corresponds with reality. When relations between Turkmenistan and Russia were bad, Turkmenistan worked out projects to bypass Russia. It signed a series of tentative agreements with the potential transiters, namely Turkey, Azerbaijan, and Iran, and even started to build sections of TCP in Georgia with massive support of the USA. However, after Russia has made price concessions and agreed to transit Turkmen gas, Turkmenistan slowed down the realization of its plans. Our calculations suggest that the only way to prevent TCP and Nabucco if Russia credibly commits to transit Turkmen gas. Otherwise, the Caspian producers will build the pipelines bypassing Russia, in spite of all the difficulties, if Russia does not prove its ability to commit.

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[8] See Hubert and Suleymanova [2006] for more details.

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Appendix A

In this section we describe the procedure used to estimate the demand for FSU gas. As mentioned in chapter 1 we derive the residual demand function based on European gas consumption data and on information on supply quantities and costs of all European exporters. We take that consumption of gas Q is exogenously given and use the figures from Petroleum [2003] and International Gas Union Report (2006). The information on capacities and marginal costs mc of all exporters are taken from de L'Energie [2002].

We obtain the import demand for gas in Western Europe by deducting from the consumption of a corresponding year, quantities Q^{dom} covered by domestic production of the EU countries. The rest $Q^{im} = Q - Q^{dom}$ is imported from the Former Soviet Union (FSU) producers and "other" exporters. To derive the residual demand for FSU gas we assume that a reduction of supply from FSU would lead to an increase in supply from "other" sources q_{-FSU}, rather than a change in total demand. Hence, the associated changes in price are determined by the cost of the marginal supplier who replaces, or is driven out by, FSU gas. Figure 2 illustrates the approach to estimation of the demand function.

Suppose Russia supplies q_{FSU} out of total Q^{im}. According to the data in Observatoire Mediteranen de L'Energie(2003), Nigeria LNG is the most expensive non-FSU gas producer. It supplies about 5 bcm/a. The second most expensive supplier is Oman with 1 bcm/a.

Continuing down to the cheapest exporter, we end up with Algeria. If Russia increased its supply it would squeeze out the most expensive competitor first, the second most expensive exporter next and so on. Thus, we derive the demand for FSU gas as $q_{FSU} = Q^{im} - q_{-FSU}(mc)$.

The gas market is not perfectly competitive and the price for gas includes a substantial mark up on marginal cost. To obtain a realistic picture of the price for FSU gas we inflate the marginal cost by a mark-up of 20%. Finally, assuming a linear form of the inverse residual demand function, we estimate the parameters of the demand for FSU gas. For all three time perspectives we obtain price elasticities at equilibrium consumption around - 3.5. The high elasticity of demand reflects the flexibility of the European buyers in the choice of a producer. The obtained elasticity is close by its value to the estimates for the European market provided in Boots et al. [2004].

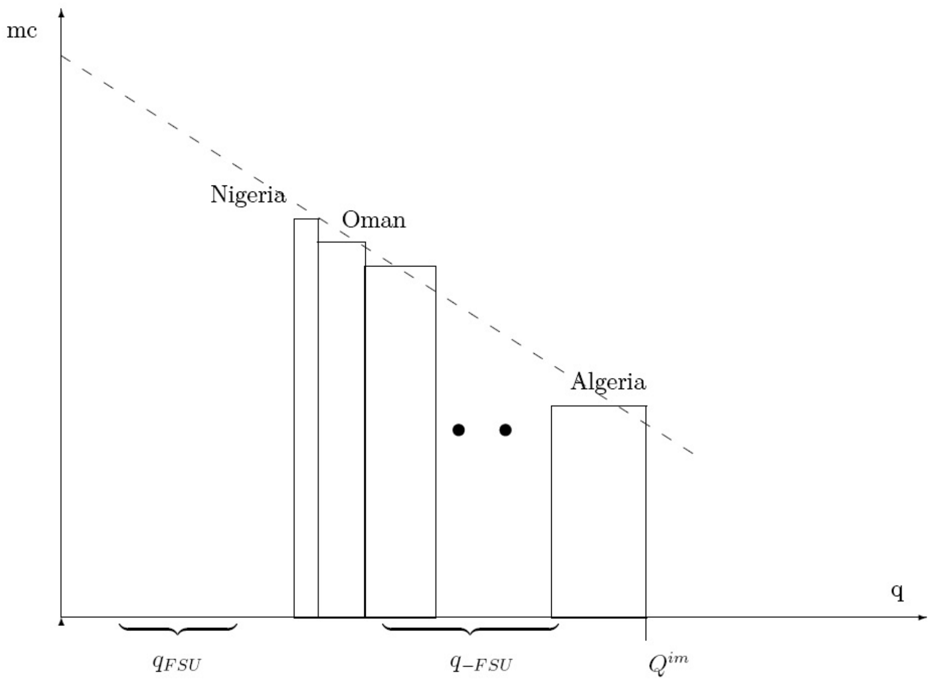

Figure 1: Estimating the demand for FSU gas

Figure 1: Estimating the demand for FSU gas.

Appendix B

In this section we prove proposition 4 providing an example of a superadditive game (N, w) in which the solution of Maskin (2003) does not result in any equilibrium. We consider a game of four players $N = \{a, b, c, d\}$. Let the players arrive to the game in the natural order θ: (a, b, c, d) and when player d enters the game, he meets a coalition structure $\{\{a\}, \{b\}, \{c\}\}$. For simplicity we will omit additional brackets and write $P = \{a, b, c\}$. In principle, player d can be allocate to any of the three coalitions (players), or start a new coalition. To determine the equilibrium allocation we must apply axiom (iii) of Maskin (2003). According to this axiom, the player is allocated to the coalition to which his gross marginal contribution is the largest. Let the values of the partition function be the following:

$$\begin{aligned}
w(a;\{a,b,c,d\}) &= 3\\
w(b;\{a,b,c,d\}) &= 3\\
w(c;\{a,b,c,d\}) &= 3\\
w(d;\{a,b,c,d\}) &= 1\\
w(ad;\{ad,b,c\}) &= 5\\
w(bd;\{a,bd,c\}) &= 5\\
w(cd;\{a,b,cd\}) &= 5\\
w(b;\{ad,b,c\}) &= 1\\
w(c;\{a,bd,c\}) &= 1\\
w(a;\{a,b,cd\}) &= 1\\
w(c;\{ad,b,c\}) &= 2\\
w(a;\{a,bd,c\}) &= 2\\
w(b;\{a,b,cd\}) &= 2
\end{aligned}$$

First, we notice that the game is superadditive that is for any S_i and S_j the following holds $w(S_i;P) + w(S_j;P) \leq w(S_i \cup S_j; P_{S_i \cup S_j})$:

$$\begin{aligned}
\forall\ S \neq d \ \text{ such that } \ S \in \{a,b,c,d\}: \quad & w(S;\{a,b,c,d\}) = 3 \ \ w(d;\{a,b,c,d\}) = 1\\
& w(S \cup d; P_{S \cup d}) = 5 > 3+1
\end{aligned}$$

The superadditivity implies that player d will not start a new coalition, since his contribution to any coalition is greater than his stand alone value. Let's show that d also can not be allocated to a, b, or c:

(i) d can not be allocated to a. We find that

$$w(bd;\{a,bd,c\}) - w(b;\{ad,b,c\}) > w(cd;\{a,b,cd\}) - w(c;\{ad,b,c\}) \ \ 4 > 3$$

this means that coalition a will compete for player d with coalition b. We check that

$$w(ad;\{ad,b,c\}) - w(a;\{a,bd,c\}) < w(bd;\{a,bd,c\}) - w(b;\{ad,b,c\}) \ \ 3 < 4$$

hence, player d can not be assigned to a.

(ii) d can not join b. The best alternative to b is c, because

$$w(ad;\{ad,b,c\}) - w(a;\{a,bd,c\}) < w(cd;\{a,b,cd\}) - w(c;\{a,bd,c\}) \quad 4 < 3$$

Morevore, the contribution of d to coalition c is greater than to b

$$w(bd;\{a,bd,c\}) - w(b;\{a,b,cd\}) < w(cd;\{a,b,cd\}) - w(c;\{a,bd,c\}) \quad 3 < 4$$

therefore, d will not be allocated to b

(iii) c can not hold d. Under the partition $\{a,b,cd\}$ the relative contribution of d to a is larger than to b

$$w(bd;\{a,bd,c\}) - w(b;\{a,b,cd\}) < w(ad;\{ad,b,c\}) - w(a;\{a,b,cd\}) \quad 4 < 3$$

this means that c has to compete with a to get d. In this case, however,

$$w(cd;\{a,b,cd\}) - w(c;\{ad,b,c\}) < w(ad;\{ad,b,c\}) - w(a;\{a,b,cd\}) \quad 3 < 4$$

so we infer that d will not join c

Hence, we have shown that there is no equilibrium allocation for d and proposition 4 is proved.

Appendix C

To prove proposition 5 we again take an example of four players $N = \{a, b, c, d\}$. We consider the game, which the players enter in natural order θ: (a, b, c, d). Let player d enters the game when the players are organized in partition $P = \{a, b, c\}$. Below we provide a partition function for which there exist more than one equilibrium allocation of d.

The values of the partition function be the following:

$$\begin{aligned}
w(a; \{a, b, c, d\}) &= 4 \\
w(b; \{a, b, c, d\}) &= 4 \\
w(c; \{a, b, c, d\}) &= 4 \\
w(d; \{a, b, c, d\}) &= 1 \\
w(ad; \{ad, b, c\}) &= 5 \\
w(bd; \{a, bd, c\}) &= 5 \\
w(cd; \{a, b, cd\}) &= 5 \\
w(b; \{ad, b, c\}) &= 3 \\
w(c; \{ad, b, c\}) &= 2 \\
w(c; \{a, bd, c\}) &= 2 \\
w(a; \{a, bd, c\}) &= 3 \\
w(a; \{a, b, cd\}) &= 1 \\
w(b; \{a, b, cd\}) &= 1
\end{aligned}$$

We check that the game is superadditive:

$$\forall\ S \neq d \ \text{ and } \ S \in \{a,b,c,d\}: \quad w(S;\{a,b,c,d\}) = 4 \ \ w(d;\{a,b,c,d\}) = 1 \tag{5}$$

$$w(S \cup d; P_{S \cup d}) = 5 \geq 4+1$$

Notice that all externalities are nonpositive: for any $i \neq j$: $w(i;\{a,b,c,d\}) \geq w(i;\{jd,..\})$:

$$\begin{aligned}
w(a;\{a,b,c,d\}) = 4 &\geq w(a;\{a,bd,c\}) = 3\\
w(a;\{a,b,c,d\}) = 4 &\geq w(a;\{a,b,cd\}) = 1\\
w(b;\{a,b,c,d\}) = 4 &\geq w(b;\{ad,b,c\}) = 3\\
w(b;\{a,b,c,d\}) = 4 &\geq w(b;\{a,b,cd\}) = 1\\
w(c;\{a,b,c,d\}) = 4 &\geq w(c;\{ad,b,c\}) = 2\\
w(c;\{a,b,c,d\}) = 4 &\geq w(c;\{a,bd,c\}) = 2
\end{aligned}$$

Thus, the merger of d and any player imposes a loss on a third party.

Now we proceed with the allocation of player d. Applying axiom (iii) of Maskin (2003), we compare the contribution of d to different coalitions.

(i) d can be allocated to a. We find that

$$w(bd;\{a,bd,c\}) - w(b;\{ad,b,c\}) < w(cd;\{a,b,cd\}) - w(c;\{ad,b,c\}) \ \ 2 < 3$$

that means that coalition a will compete for player d with coalition c. Since

$$w(ad;\{ad,b,c\}) - w(a;\{a,b,cd\}) > w(cd;\{a,b,cd\}) - w(c;\{ad,b,c\}) \ \ 4 > 3$$

according to the solution of Maskin (2003) player d can be allocated to a.

(ii) d can be allocated to b. We find that the best alternative to b is c, since

$$w(ad;\{ad,b,c\}) - w(a;\{a,bd,c\}) < w(cd;\{a,b,cd\}) - w(c;\{a,bd,c\}) \ \ 2 < 3$$

We observe that the contribution of d to b is larger than to c

$$w(bd;\{a,bd,c\}) - w(b;\{a,b,cd\}) > w(cd;\{a,b,cd\}) - w(c;\{a,bd,c\}) \quad 4 > 3$$

therefore, we conclude d can join b.

(iii) c can not hold d. Under the partition $\{a,b,cd\}$ the contributions of d to a and b are equal

$$w(bd;\{a,bd,c\}) - w(b;\{a,b,cd\}) = w(ad;\{ad,b,c\}) - w(a;\{a,b,cd\}) \quad 4 = 4$$

In this case we should check both coalitions, whether d can join them

$$w(cd;\{a,b,cd\}) - w(c;\{ad,b,c\}) < w(ad;\{ad,b,c\}) - w(a;\{a,b,cd\}) \quad 3 < 4$$
$$w(cd;\{a,b,cd\}) - w(c;\{a,bd,c\}) < w(bd;\{a,bd,c\}) - w(b;\{a,b,cd\}) \quad 3 < 4$$

thus, c fails to attract d from both a and b.

According to the results of (i) and (ii), we have obtained that d can be allocated to both a and b. Hence, we have multiple equilibria.

Appendix D

In this section we prove that proposition 5 provides a sufficient condition for an equilibrium under the solution of Maskin (2003) to exist.

Consider an arbitrary game (N, w) and fix some order θ. Let's take an arbitrary node (P, i), in which player i enters the game and observe partition P with coalitional profits described by function $\widetilde{w}$. Assume that there is the only coalition S such that its worth depends on the allocation of i: $\widetilde{w}(S; P_{S' \cup i}) \neq \widetilde{w}(S; P_{S'' \cup i})$ for any $S^{'}, S^{''} \neq S$.

Since the contribution of i to coalitions in $P \setminus S$ is always the same, we can arrange these coalitions according to the contribution of i in ascending order. Denote by $S^{'}$ the coalition with the greatest contribution $\widetilde{w}(S^{'} \cup i; P_{S' \cup i}) - \widetilde{w}(S^{'}; \cdot) \geq \widetilde{w}(S^{''} \cup i; P_{S'' \cup i}) - \widetilde{w}(S^{''}; \cdot)$ where $S^{''} \in P \setminus S \setminus S^{'}$. To prove the proposition it is enough to consider whether the player can be allocated to $S^{'}$ or S, since by our assumption $S^{'}$ can overbid all other coalitions $P \setminus S \setminus S^{'}$.

(i) if the contribution of i to S under $P_{S' \cup i}$ is smaller than the contribution of i to $S^{'}$, then player i is allocated to $S^{'}$ according to axiom (iii), since

$$\widetilde{w}(S^{'} \cup i) - \widetilde{w}(S^{'}) \geq \widetilde{w}(S \cup i; P_{S \cup i}) - \widetilde{w}(S; P_{S' \cup i}) \ \ \forall\ S \in P \setminus S^{'} \quad (6)$$

(ii) if the contribution of i to S under $P_{S' \cup i}$ is greater than the contribution of i to $S^{'}$, then player i is allocated to S, because

$$\widetilde{w}(S \cup i; P_{S \cup i}) - \widetilde{w}(S; P_{S' \cup i}) \geq \widetilde{w}(S^{'} \cup i) - \widetilde{w}(S^{'}) \ \ \forall\ S^{'} \in P \quad (7)$$

Thus, we have shown that the equilibrium allocation exists and hence, proposition (6) is proved.

Now we use proposition (6) to explain why we do not encounter the problem of non-existence. First, notice that if the node (P, i) is such that $|P| \leq 2$ following Maskin (2003) we can proved that an equilibrium exists. For the other nodes we distinguish two cases: (I) when i is a producer and (II) when i is a transiter.

(I) Suppose a producer enters the game. Since in our analysis we have only two producers two situations are possible: (i) the other producer has already arrived and (ii) the other producer will enter the game later.

(i) the producer can face the following coalitions: a coalition including the rival producer and coalitions consisting of transiters only. The value of the coalition with the other producer may depend on which alternative the producer selects. All coalitions containing only transiters are not affected by the choice of the producer, their value will be zero if the producer does not join them. Thus, there is only one coalition such that $\widetilde{w}(S; P_{S' \cup i}) \neq \widetilde{w}(S; P_{S'' \cup i})$ and we can apply proposition 6.

(ii) if the other producer comes later, the present coalitions include only transiters. The value of coalitions with the transiters, who are complementary to the producer, does depend on which alternative the producer chooses. But in principle, the allocation of the producer may affect the allocation of the other producer and hence, it might matter for the transiters who are complementary to the other producer. If these transiters form one coalition or there is only one such transiter, we can use proposition 6. Otherwise, there are two coalitions for which the allocation of the producer might be relevant. Fortunately, even in this case we can use proposition 6, because

(a) If Russia enters the game and Turkmenistan follows, then the coalitions at question are Azerbaijan and Iran. These players are symmetric and the allocation of Russia affects them in a similar way, therefore it is enough to consider only one of them. If there is only one coalition is such that $\widetilde{w}(S; P_{S' \cup i}) \neq \widetilde{w}(S; P_{S'' \cup i})$, we can use proposition 6.

(b) If Turkmenistan enters the game and Russia follows, then the coalitions at question are Ukraine and Belarus. We find that the allocation of Turkmenistan does not change the preference of Russia on which transiter to join. Thus, for all coalitions which $\widetilde{w}(S; P_{S' \cup i}) = \widetilde{w}(S; P_{S'' \cup i})$ and by proposition 6 the equilibrium exists.

(II) Now we look at the situation when a transiter enters the game. Here, we will distinguish three cases: (i) both producers are present, (ii) a complementary producer is absent, and (iii) both producers are absent.

(i) in the presence of both producers the allocation of the transiter is relevant for at most two coalitions, those including the producers, since his contribution to any other coalition is zero. The situation reduces to $P \leq 2$ and the result of Maskin (2003) can be used.

(ii) in this case we should take into account that the allocation of the transiter may change the allocation of the complementary producer, who comes later. In this respect, the allocation of the transiter may affect the value of the coalition including the other producer. Besides, the allocation choice matters for the other complement transiter, if he is present. The other coalitions are irrelevant, their value is zero and we can neglect them. Hence, we obtain that only two coalitions are relevant and we again use the proof of Maskin (2003).

(iii) when both producers are absent, the observed coalitions consist of transiters. We are interested only in the case when there are three coalitions. The allocation of the transiter might matter only for the transiters complementary to the other producer. Since the allocation of the transiter may change the preferences of his complementary producer that, in turn, by (ii) of (I) can lead to the change in the allocation of the other producer. However, as we have discussed in (ii) of (I), in this case the equilibrium will exist.

Appendix E

In the table below we report the profits of essential partitions, namely for coalitions including producers. The profits are calculated for different variants with regard to investment options available. The left part of the table starts with the variant "all options" which is followed by "minus one option" figures, the excluded option is given in the title. Thus, "-Upgrade" means, that the players can not invest in the upgrade of the old Ukrainian system, but have all the others options available. The right part of the table take "status quo" variant as a basis. In every next row we include one pipeline - the one given in the heading.

Table 3: Coalitional profits in $bn

		$\{t\}$	$\{t,a\}$	$\{t,a,i\}$	$\cup\{t\}$		$\{t\}$	$\{t,a\}$	$\{t,a,i\}$	$\cup\{t\}$
$\{r\}$	all	4.6; 0	3.7; 2.2	3.0; 3.2	5.7	status quo	0; 0	0; 0	0; 0	0
	-Upgrade					+Upgrade				
	-Yamal2					+Yamal2				
	-NEGP	0; 0	0; 3.0	0; 4.7	5.2	+NEGP	4.6; 0	4.6; 0	4.6; 0	5.7
	-TCP		4.6; 0	3.7; 2.2		+TCP		0; 3.0	0; 3.0	3.2
	-TCP,Nab		4.6; 0	4.6; 0		+TCP,Nab		0; 3.0	0; 3.0	5.2
$\{r,b\}$	all	5.8; 0	4.8; 2.1	4.0; 3.1	7.0	status quo	3.5; 0	3.5; 0	3.5; 0	3.7
	-Upgrade					+Upgrade				
	-Yamal2	5.3; 0	4.4; 2.2	3.7; 3.2	6.4	+Yamal2	5.8; 0	5.8; 0	5.8; 0	7.0
	-NEGP					+NEGP	5.3; 0	5.3; 0	5.3; 0	6.4
	-TCP		5.8; 0	4.8; 2.1		+TCP		3.1; 2.7	3.1; 2.7	5.7[a]
	-TCP,Nab		5.8; 0	5.8; 0		+TCP,Nab		3.1; 2.7	2.8; 4.0	9.3[b]
$\{r,u\}$	all	6.5; 0	5.5 ; 2.1	4.6; 3.0	7.7	status quo	6.3; 0	6.3; 0	6.3; 0	7.2
	-Upgrade	6.3; 0	5.5 ; 2.2	4.6; 3.0	7.5	+Upgrade	6.5; 0	6.5; 0	6.5; 0	7.7
	-Yamal2					+Yamal2				
	-NEGP					+NEGP	6.3; 0	6.3; 0	6.3; 0	7.5
	-TCP		6.5; 0	5.5 ; 2.1		+TCP		5.4; 2.2	5.4; 2.2	7.5[c]
	-TCP,Nab		6.5; 0	6.5; 0		+TCP,Nab		5.4; 2.2	4.6; 3.0	7.5[d]
$\{r,b,u\}$	all	6.6; 0	5.6; 2.1	4.7; 2.9	8.1	status quo	6.6; 0	6.6; 0	6.6; 0	8.1
	-Upgrade					+Upgrade				
	-Yamal2					+Yamal2				
	-NEGP					+NEGP				
	-TCP		6.6; 0	5.6; 2.1		+TCP		5.6; 2.0	5.6; 2.0	8.1[e]
	-TCP,Nab		6.6; 0	6.6; 0		+TCP,Nab		5.6; 2.0	4.7; 2.9	8.1[f]

[a] w$(\{r,t,b,a,i\};\{\{r,t,b,a,i\},\{,u\}\})$
[b] $w(\{r,t,b,a,i\};\{\{r,t,b,a,i\},\{u\}\})$
[c] $w(\{r,t,u,a,i\};\{\{r,t,u,a,i\},\{b\}\})$
[d] $w(\{r,t,u,a,i\};\{\{r,t,u,a,i\},\{b\}\})$
[e] $w(N;\{N\})$
[f] $w(N;\{N\})$

Abkuerzungen

Abkuerzung	Erklaerung
bcm/a	billion cubic meter per year
EU	European Union
FSU	Former Soviet Union
LNG	liquified natural gas
NEGP	North European Gas Pipeline
NTG	North Trans Gas
tcm	thousand cubic meter per year
TCP	Trans-Caspian Pipeline

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Selbstaendigkeitserklaerung

The work presented in this dissertation is the result of my own investigation, except where otherwise stated.